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June/July 1999
Volume 14, Number 2

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AIR & SPACE/Smithsonian (ISSN 0886-2257) is published bimonthly by the Smithsonian Institution, 900 Jefferson Drive, Washington, DC 20560. Editorial offices: 901 D St. S.W., 10th Floor, Washington, DC 20024. Advertising and circulation offices: 420 Lexington Ave., New York, NY 10170.

SUBSCRIPTION PRICES: U.S. and possessions: $20 a year payable in U.S. funds. Canada and all other countries: add $6.00 (U.S. funds) per year. Eighty-five percent of dues is designated for magazine subscription. Current issue price: $3.95 (U.S. funds). Back issue price: $5.00 (U.S. funds).Periodical postage paid at Washington, D.C., and additional mailing offices. Standard A enclosure with version #1. Permit #6238 Cincinnati, OH.

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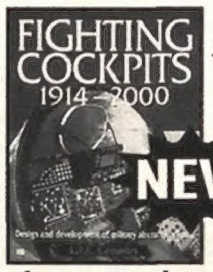

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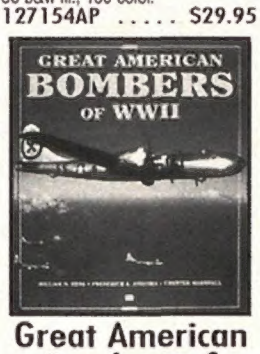

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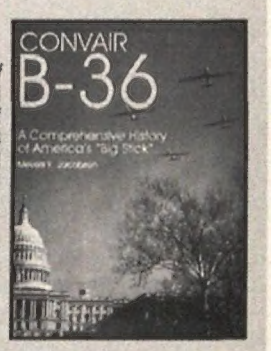

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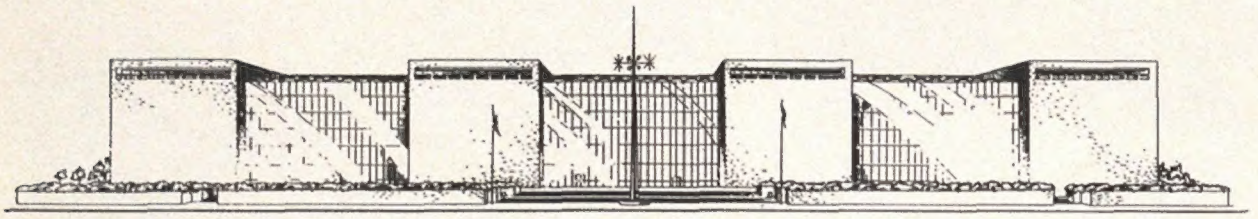

You Can Fly

There is no doubt that the United States leads the world in aviation. Most of the world's aircraft are produced here, and the rest of the world looks to us to set the standards for aviation operations and safety. As a nation, we rely heavily on air transportation to move goods and people. Because of the vast distances between its commercial centers, the United States has a time-distance challenge. The airlines do a great job, but they have to respond to the forces of the marketplace, and they cannot always take us where we need to go. So how should we get there? The answer is obvious: Fly there ourselves.

In a country that opens its skies to each and every citizen, it's hard to believe there is only one licensed pilot for every 440 people. Imagine the impact on commerce if 439 out of 440 people didn't know how to drive a motor vehicle. In today's world, this lack of knowledge puts non-pilots at a significant disadvantage.

We give our children piano lessons and we teach them to drive. We send them to school to prepare for a career and to broaden and enhance their lives. Why don't we teach them to fly so they can be more productive and flexible?

I think the reason is that we don't fully understand the value of our time and the value of being able to go where you want to when you want to. Added to that is the widespread perception that "other people" learn to fly. It is other people who leave the ground with its grinding traffic congestion and soar on wings over great distances. It is other people who transcend the norm and excel.

Yes, flying lessons cost money. Learning to fly can cost the average person several thousand dollars, about the cost of a good computer. However, once earned, a pilot's license is all you need to get into the air—you can always rent the airplane—and it is a lasting investment. With that license, flying an airplane can be as routine as driving a car.

Each year, the National Air and Space Museum and *Air & Space/Smithsonian* magazine co-host "You Can Fly." Traditionally held on the weekend before the July 4th holiday, this year the event will be held on June 26 and 27. Aviation associations and organizations will be at the Museum to show visitors the many ways one can learn to fly. Parents can learn how to invest in their children's future or boost their own lifestyle by increasing the value of their personal time.

The "You Can Fly" weekend is a great opportunity for those who live close to the Museum, but you can also get information by making a telephone call. For example, the Be-A-Pilot program is dedicated to creating opportunities for anyone 16 or older to get an introductory flight lesson. Call 1-888 BE-A-PILOT for a $35 coupon that can be taken to any of 1,600 participating flight schools. Members of the Experimental Aircraft Association provide introductory flights for boys and girls eight to 17 years old under the Young Eagles program. You can join the Civil Air Patrol and learn to fly, and the Air Explorer Scouts also has a dynamic program. The Aircraft Owners and Pilots Association is one of the most important sources of information and support for potential student pilots. And Cessna Aircraft is developing a computer-based learning program.

There are dozens of aviation-oriented colleges and universities where students can earn their degrees while learning to fly. And there is your local airport, where qualified instructors are available to teach you on an individual basis.

Aviation is so important in the United States that learning to fly should be like learning to swim—it ought to be mandatory. Once learned, flying can help all of us to better meet the demands of modern living by conquering those time and distance challenges. Come to think of it, wouldn't it be a good idea to make the "You Can Fly" weekend a nationwide event so even more people could learn how to gain the advantages of getting there by air?

—Don Engen is the director of the National Air and Space Museum.

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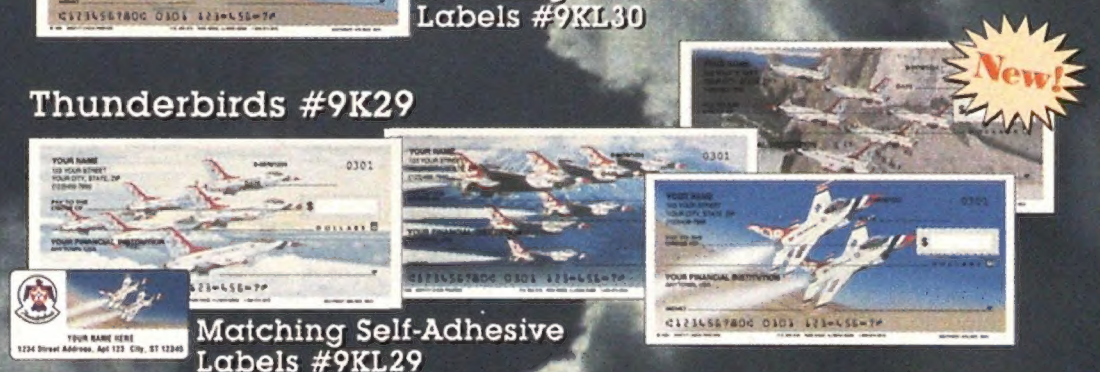

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LETTERS

A Story That Shouldn't Have Been Told?

I am a fighter pilot who flew in Korea and Vietnam and was honored to fly on Jim Jabara's wing in 1951 ("MiG Fever," Above & Beyond, Apr./May 1999). I have heard of and know fighter pilots who have shot down a friendly aircraft, and I believe that there is a code of honor whereby such pilots have sentenced themselves to a living hell, and for others to discuss the incident is taboo. I do not know whether Jim shot down an F-86 in 1953, but I consider it grossly unfair for your magazine to publish such a story about a man who is unable to defend himself (Colonel Jabara died in 1966). If in fact he did shoot down a U.S. aircraft, I say "There but for the grace of God go I." Any fighter pilot who has been in a life-or-death air-to-air donnybrook will agree.

The author states that the MiG-15 could not recover from a spin. I have discussed this with other F-86 pilots (including three aces) who engaged in air-to-air combat in Korea and who knew Jim Jabara well. Most of us witnessed MiG-15s enter a spin and recover. Air Force tests showed that although the MiG-15 did have a tendency to snap and spin under high-G conditions, it could be recovered. Your writer's allegation that Jabara took credit for two MiGs simply because he observed them in a spin will not hold water.

No one to whom I have spoken has any recollection of Jim Jabara having poor eyesight, as your writer stated. On the contrary, his record of air-to-air victories in two wars (16.5) speaks volumes about his visual acuity.

My heart goes out to Jim Jabara's descendants. I want to assure them that he was a gallant warrior, a man of honor, a superb fighter pilot, and a good friend.

—Brigadier General Alonzo J. Walter Jr.
U.S. Air Force (ret.)
Austin, Texas

John Lowery responds: I stand by the accuracy of my article, which I wrote based on interviews with the surviving people involved. I was the squadron historian and kept my notes and a carbon of the final submission. I was told that I should not mention Jabara's incident in the official history. I felt it should be told, in part to show that careful identification of your target is not *secondary to getting credit for a*

victory. For this reason, and perhaps because of the ballistics of the F-86's .50-caliber guns, we were taught to hold fire until we were no farther than 1,500 feet from the enemy aircraft. When Jabara opened fire on the F-86, he was at 3,000 feet, under ideal atmospheric conditions and with no other fighters in the area.

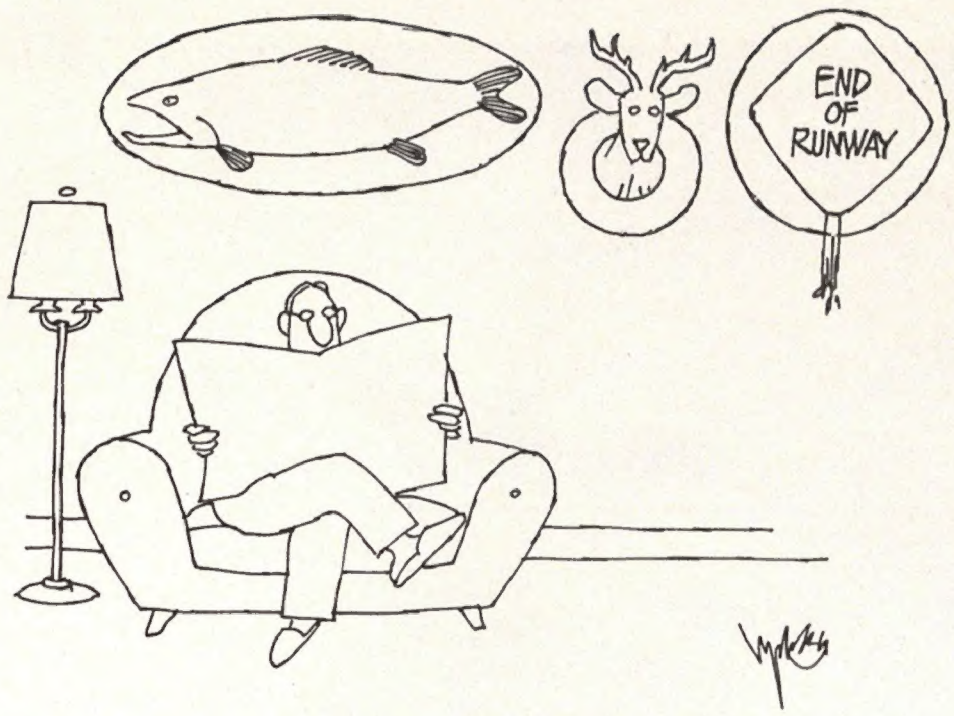
Regarding the MiG-15's spin characteristics: My source says that the aircraft did have an unrecoverable spin mode. At the ultrahigh altitudes it was able to reach, it was always very close to its low-speed buffet boundary, and thus very close to a stall/spin. Because the MiG-15's oxygen and pressurization system was comparatively primitive, some incidents of unrecoverable spins were thought to be due to pilot hypoxia. As for Jabara's getting credit for the spinning MiG-15s, General Walter should read the Fourth Wing intelligence debriefing reports on Jabara's ninth and 10th kills, both on the same mission. He should also note that there is no gun camera film for these kills. Incidentally, I have recently learned that on this mission, Lieutenant Frailey was not Jabara's wingman. However, the number-two flight member can verify the transmissions describing the spinning aircraft.

On the subject of Jabara's eyesight, before flying with him I was briefed that he apparently had bad vision, since his wingman frequently had to vector him toward a bogey. When I served as his wingman, he required every member of the flight to take a "MiG pill," which I believe today is called an "upper." These were supposed to make you see better.

Regarding an honor code: What are the legal repercussions of a coordinated effort to hide the destruction of a U.S. fighter and the falsification of the official record of the event?

I agree with General Walter that Colonel Jabara was a gallant warrior. His story is one that needed telling because it could indeed happen to any of us, if we let the drive for personal glory overcome both our training and our good judgment.

I put in my 100 missions in the 4th Fighter Interceptor Group (I was the one who painted the group sign shown in the photograph on page 17), so I readily recognized the story about Jabara shooting down Frailey. We used to call Jabara "Cousin Weak-Eyes" for his propensity to shoot at anything. Jabara wasn't alone in this respect. A pilot in my squadron (the 335th) finished off an F-86 that was already smoking and going down. He was grounded and sent Stateside, summary punishment Jabara never received.



My cousin, Dale "Mac" McMullen (deceased), was a pilot in my flight, and once, while flying wing with group commander Colonel Royal Baker (an ace and also deceased), he fired on an F-86. He missed and broke off. On the ground, the colonel approached my cousin, who thought he was about to catch hell for firing at a friendly. Instead, the colonel said, "Mac, you had that guy wired, why didn't you press in?" Mac said that it was an 86. The colonel said, "The hell it was." Gun camera film confirmed Mac's story.

On my second mission, our flight was attacked by two MiGs and we all ended up in clouds. Coming out of the clouds after a few seconds, I lined up on a target below, adrenaline pumping…then recognized the thin trail of black smoke that differentiated an F-86 from a MiG; the aircraft was one of our flight.

—Lee Brewer
Friday Harbor, Washington

Touchy Subject

I had to write after seeing that the Airshow Schedule (Apr./May 1999) included the Shell Air & Sea Show in Fort Lauderdale. This show is held at a beach, with no aircraft on the ground. To me, half of a real airshow is being able to see the hardware up close and touch it. Back when south Florida had the Miami Airshow, my son used to delight in sitting in the cockpits of airplanes and helicopters and walking through the cargo holds of C-5s and C-130s. I sure hope holding airshows at non-airport locations isn't a trend.

—Donald L. Curren Jr.
Coral Springs, Florida

Not Much to Look At

In 1949, a friend and I, civil service engineers at the Naval Air Test Center at Patuxent River in Maryland, took a vacation trip down the Atlantic coast to Key West. We had heard that they were testing aerial weapons at the Banana River Naval Air Station, which was along our way, so we planned to stop by to check out the job opportunities.

As we were driving to and across the causeway from Highway 1 to the air station, we observed the barrenness of the place ("The Year the Rockets Came," Apr./May 1999). We agreed that we wouldn't like to live around there. And so I turned around and headed back to the mainland with the comment: "Nothing much will come of this place." After "this place" evolved into Cape Canaveral, no one ever again took my advice about job opportunities, real estate, investments…

—Martin A. Snyder
Concord, California

Misguiding Light

I was a principal member of the team that developed the laser-guided bomb, and my recollection of events differs from the narrative in "Guiding Light" (Apr./May 1999). The article combines events that took place during two separate contracts. The second contract was the one under which the practical laser-guided bomb was developed. It was also during the second contract that the problem of "satellite beams," which your article mentions, occurred.

After the guided bomb was launched from the test aircraft, it acquired the target, a white plywood panel. The bomb guided perfectly until it reached an altitude of about 400 feet. Then it suddenly changed course, impacting about 140 feet in front and left of the target. Contrary to your account, we could not determine from the recorder's sparse data what had happened.

To find out what the bomb was tracking, we decided to fly a simulated trajectory of the bomb's path. The Air Force took the side door off a Huey helicopter and gave me a gunner's belt to allow me to sit with my legs dangling from the side of the chopper. I had taken another seeker and mounted a rifle scope on it, and as the Huey flew, I looked through the scope to see what the bomb was tracking. At about the expected point, the seeker suddenly began targeting a tree about six feet tall.

We repeated the experiment several times and kept getting the same result. One of the Eglin personnel cut down the tree with his hunting knife. The aim point shifted to the ground between the location

CAN YOU IDENTIFY THIS AIRPLANE?

UNIDENTIFIED FLYING OBJECT

The airplane pictured above is a:

- **Fouga Magister CM.170**
- **Beechcraft Twin Quad**
- **Lear Fan 2100**
- **CASA C.212V**

For the fourth in our series of six contests, we've made the task a little more difficult than the first three. But the rules haven't changed: You can qualify for six prizes, one of which will be awarded after each photograph is published, and one grand prize at the conclusion of the contest:

- **awarded following each edition—a Garmin GPS III satellite navigator**
- **GRAND PRIZE—flight training worth $2,000 from the Be-A-Pilot™ program.**

All you have to do is select an answer from the choices listed above, then mail a postcard with your name, address, and answer to: **AIR & SPACE, UFO Contest, 901 D Street SW, 10th Floor, Washington, DC 20024**. Identify the airplane correctly and you'll qualify for the drawing to award the prize.

Before entering, please read the detailed rules, which are posted on page 87.

WINNER WINNER WINNER WINNER WINNER

Winner of the second UFO Contest is **Stan Seashore** of Arizona, one of many readers who correctly identified the object as the **Northrop N-23 Pioneer**, a civil version of the U.S. Air Force YC-125 Raider light transport.

of the tree and the target. We concluded the bomb was tracking a spurious laser beam.

The laser was dismantled. All the parts inside the telescope were supposed to have been painted flat black. However, the assembly person had missed one screw head, and the laser beam was reflecting from the shiny screw. A dab of the anti-reflection paint fixed the problem.

At the same time, I invented a circuit that enabled the seeker to discard smaller beams and guide only on the main beam. Some form of that circuit is included in virtually all laser pulse receivers today. The combination of the laser repair and the seeker modification did the trick, and the next bomb nailed the target panel.

—Lilburn Smith
Weatherford, Texas

Ahead of His Time

In "Let the Show Begin" (Viewport, Apr./May 1999), Don Engen states that the outside loop had been perfected by 1915. The aviator credited with performing the first outside loop is Jimmy Doolittle, and he didn't do it until 1927.

—James J. Skiles
Madison, Wisconsin

Shaddup!

Jerry Van Kempen has a grossly inflated sense of his own importance to think that he is what makes Bob Hoover or Patty Wagstaff or Sean Tucker or any other airshow performer look good ("The Voice," Apr./May 1999). Maybe the rubes at some county airshow would find the announcer useful, but the rest of us only want to hear who the performer is, who the sponsor is, and what we can expect. Unfortunately, most of these morons like to hear themselves babble.

—William R. Simpson
Ann Arbor, Michigan

A Premature Obituary

In "Kaman Decision" (Soundings, Apr./May 1999), Phil Scott writes: "Today the only helicopters flying without turbine powerplants are wheezing museum pieces." In fact, several manufacturers continue to produce piston-powered helicopters; Robinson Helicopter, for instance, currently makes two very popular models.

—Jim Gates
Redondo Beach, California

The Country Club Set

Contrary to John Fleischman's assertion, a serious accident did occur at the Aviation Country Club of Long Island ("High Society," Feb./Mar. 1999). During the club's 1932 autumn airshow, Pete Brooks tried to snap-roll out of an inverted low-level fly-by and ended up demolishing his Monocoupe 110 and nearly killing himself. They patched his skull with metal. (It didn't seem to affect his flying skills, although his personal life became a shambles.) In addition, Brooks was not a band leader. That club member was Roger Wolfe Kahn.

—John Underwood
Glendale, California

Something Old, Something New

I have subscribed to your magazine for a couple of years. I like the articles on vintage aircraft, but there are just not enough about newer aircraft, such as the F-22, the B-2, and plans for the YF-23.

—Ray Walker
Erath, Louisiana

I am only 12 but I still love your magazine! The thing I love the best about it is when you put things in about World War II planes and fighters. Could you put more things in about World War II fighters?

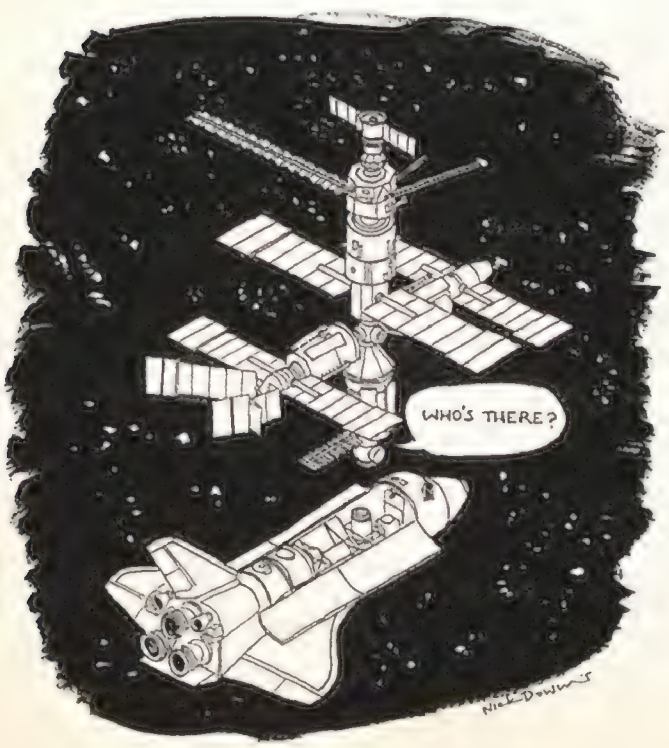
—David Low
Tallahassee, Florida

So Would We

In the Letters column of the last issue, William Burrows cited my book, *SR-71 Revealed*, as evidence that the drone-modified A-12s were called M-12s. I believe Jay Miller to be correct in his facts, so in the third printing of the book, I will change "M-12" to "M-21."

I wrote *SR-71 Revealed* primarily to give the reader a sense of what it was like to fly the SR-71 on operational sorties. I leave the historic research to those who are inclined to it. I would rather be flying.

—Col. Richard H. Graham
U.S. Air Force (ret.)
Plano, Texas



The Story Behind "High Flight"

Many of your readers know my brother John's poem, "High Flight." However, there is one fact about the poem that many of them are probably not aware of. Our parents were missionaries in China and brought us up in strict Christian surroundings, with prayers and Bible readings at home. However, before John enlisted in the Royal Canadian Air Force, he had doubts about religion and eventually lost his Christian belief. But the thrill of flying, especially a Spitfire, awakened his lost beliefs. The last line of his poem, "[I've] Put out my hand and touched the face of God," attests to this.

His death a few months after sending "High Flight" to our parents was a terrible shock, but the return of his religious belief was a good source of comfort to us.

—David Magee
Rye, New York

Corrections

Apr./May 1999 "Guiding Light": The shelters shown in the photograph on p. 73 were destroyed by F-111Fs, not F-117s.

"Lifeline," p. 51, 3rd column, 1st paragraph: The last sentence should have referred to pilots learning to take off with one engine out, not with one engine. The error was introduced during copy editing.

Airshow Schedule: (1) As we went to press, the Thunderbirds' performance schedule had been suspended in the wake of a recent accident. (2) The Washington State airshow scheduled for July 17 and 18 is at the Olympia Flight Museum, not the Seattle Museum of Flight. We regret that error, which originated in a schedule from the International Council of Air Shows.

Poster Key: Number 32 is a Constellation from the Constellation Group, Inc., not Save-A-Connie.

Write to us at: Letters, Air & Space/ Smithsonian, *901 D St. SW, 10th Floor, Washington, DC 20024. Please type or print clearly. You must include your full address and daytime phone number. All letters are edited for publication.*

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Final Exams

"Cat's up and F-1 is ready to rock and roll," announces the mini-boss. The first F/A-18F Super Hornet ever produced slides into the catapult shuttle of the USS *Harry S. Truman*. It's 8:30 a.m. The aircraft carrier is plowing through whitecaps straight into the wind, 100 miles east of Jacksonville, Florida. Rays of sun cut through billowing gray clouds. "Is that rain right up there?" says Mike Trebino, leaning on the windows of the control tower and pointing toward a greenish-gray curtain ahead. "Let's just head through it a minute."

Trebino leads the Super Hornet flight test program, and this may be the most dangerous single day of three years of testing. Seven Super Hornets (the name given to the model E, which has a single seat, and the F, which has two) have been built, and other than a five-day stint in 1997, this is the first time the Navy's new fighter is being thoroughly tested at sea. It is a process almost unrecognizable from the testing of the F/A-18A just 20 years ago. Then, says Trebino, "we marched ahead, maybe not quite with blinders on, but with a lot more risk."

Not anymore. Ten days ago in Norfolk, Virginia, 15 pallets of electronic monitoring equipment were crammed inside the admiral's bridge, two stories below the control tower, creating, in Trebino's words, "a mini version of NASA Houston" capable of live monitoring of dozens of parameters from each airplane. The Super Hornets have already been exhaustively tested on dry land: now it's time to see how they perform landing and taking off on a carrier at sea.

These sea trials will last two weeks. So far the airplanes have taken off and landed in different wind speeds and crosswinds. They have taken off and landed with asymmetrical loads and with one engine out. They have taken off and landed using the automatic carrier landing system. Last night, they took off and landed on a carrier at night for the first time. And each time, some 50 engineers from Boeing, wearing tennis shoes and T-shirts, and hunched over laptop computers, radios, and strip charts, compare the airplanes' actual performance to predictions. "The engineers look at all the data," says Trebino, "and if the airplane is performing according to our predictions, they'll give the thumbs-up. If not, then we'll have to figure out why before going further." After every flight, the new real-world information will be re-fed into the engineers' computer models, a process that continually refines the models.

Today, Trebino and the test pilots will determine the Super Hornet's minimum catapult launch speed. The airplanes, fully loaded, will be catapulted off the deck at lower and lower speeds until they either drop more than 10 feet off the end of the carrier or the pilots say stop, whichever comes first. The F/A-18F's flight manual will be written from today's tests.

RON BOOKOUT/BOEING

F-1 wiggles its flight controls and throttles up. The afterburners glow orange. There is exactly 34 knots of wind across the deck. For every knot less, the airplane will sink three to four feet. WHAM! F-1 shoots down the deck and into the air. A voice barks at Trebino through the radio. "It's huddle time," he says. The airplane, at its highest launch speed, sank two feet more than had been predicted. But Trebino isn't worried. "Twenty years ago we just pressed on until we hit the limit," he says, hurrying to a meeting with the engineers, "but now we can roll the information back into the simulators right away and our next launch should be right where we want it. Still," he says, "this is the most intense thing we do."

—Carl Hoffman

NANCY BRIGHAM

Dishing John Glenn

They billed it "Tribute to John H. Glenn, Jr., A Great American Hero." As one of the organizers cracked, "It's time to bring John back down to Earth." That's not exactly how the gala roast, sponsored by the Astronaut Scholarship Foundation and the U.S. Space Camp Foundation, turned out. If anything, the 575 VIPs who paid as much as $1,000 a plate to dine with Glenn last February in Orlando went home convinced that America's first in orbit and oldest aboard the space shuttle probably hung the moon.

They were celebrating the 37th anniversary of Glenn's pioneering flight in the Mercury capsule *Friendship 7* and welcoming the 77-year-old Ohio senator home from his controversial but wildly popular nine-day geriatric science mission aboard the shuttle *Discovery*. The evening featured a sumptuous five-course meal, interspersed with Disney-caliber song and dance on a camera-laden stage. Several friends and former astronauts—Gene Cernan of Gemini 9, Apollo 10, and Apollo 17 and Wally Schirra of Sigma 7, Gemini 7 and Apollo 7 among them—did their best to de-orbit John Glenn in time for dessert.

The cheap shots came in rapid-fire succession. "Was I envious of John or jealous? No," Schirra said, "I wasn't that old. I didn't need the flight time. I had 300 hours. John had five. But I too would do anything to get out of that crazy goddamned U.S. Senate." Cernan put on a Glenn costume—a beat-up spacesuit with a big bow tie and a cane—and hobbled onto the stage for a sendup interview with Walter Cronkite. "Because of your hero status, will you have any special privileges aboard the shuttle?" Cronkite asked. "I'll get to pre-board," Cernan said, "and I'll have my choice of Geritol or Metamucil to mix with my Tang."

"I think this age thing has been a little bit overdone," Glenn said in rebuttal. "There's no truth whatsoever to the rumor that NASA refused to let me have a spacewalk because they were afraid I'd wander off someplace. And there's also no truth to the claim that I was the first 77-year-old to leave Florida in something other than a Winnebago."

Dessert wasn't just any old solid white chocolate space shuttle. This one was poised nose-up on a ring of icing points that were hardened and air-brushed orange and sitting in a pool of peach and raspberry sauces. It landed on tables only after a videotape replay of a shuttle countdown and liftoff. Tuxedoed servers stood with lit sparklers, waiting for the video to show the shuttle dropping its booster rockets.

But even the dessert couldn't upstage Glenn, who enjoyed a handful of standing ovations. A videotaped tribute from one of his biggest fans, "Tonight Show" host Jay Leno, summed up the evening's sentiment: "The guy's had a perfect life—the best American who ever lived." For a nightcap, Glenn autographed the party favors—Mattel's Hot Wheels Action Pack of toys commemorating his two missions in miniature. The signature line stretched 45 minutes.

—Beth Dickey

Baled Out

When neighbors at Albany International Airport in upstate New York complained about the noise of airplanes running up their turboprop engines, the facility's engineers came up with a simple and decidedly low-tech solution: Hay. About 16,000 bales of it.

Albany's "Hush House," put into service in February, is the largest of only three such structures in the country. Constructed of hay bales stacked on a base of some 600 railroad ties, which keeps ground moisture at bay, it has been described as looking like a giant farmer's market stand protected by a swimming pool cover.

Albany is the eastern regional maintenance hub for American Eagle and Business Express Airlines. Neighbors rarely complained about the routine flights, but they were bothered by the engine run-ups, which are part of the aircraft maintenance. That activity usually takes place between 10 p.m. and 1 a.m. and requires the engines to run for as long as 20 minutes at a time. Area residents made sure that airport managers knew they were missing their sleep.

Engineers considered a variety of sophisticated options, including plastic structures, but they would have cost the airport as much as $2 million. Then they learned what California's Fresno Yosemite and San Luis Obispo airports had done to solve the same problem. They muffled the sound of their engines with hay, which costs only $1.50 a bale.

"I wish I could tell you that there was one genius here who came up with this idea," said Fresno Airport spokesperson Patti Miller. "Westair Airlines and the airport folks came up with the idea of the covered hay bales."

Originally the Westair and Fresno people thought they'd just use the canvas-

GEOFFREY CLIFFORD

The latest in simulators: Its operators claim the Fly by Wire ride near Queenstown, New Zealand, is the world's fastest ride. It may also be the most expensive: Eight minutes in the tethered craft runs $129. Suspended from a 350-foot tower, Fly by Wire can reach 120 mph and pull three Gs. A 60-horsepower engine provides the initial kick; the rider controls the throttle and steering. "Using your speed and momentum will get the best performance from the plane," its operators advise. The fine print notes that the ride "complies with all Occupational Safety and Health requirements."

covered hay bales until they came up with something better. That was more than 15 years ago. Once the hush house was in place, the complaints dropped, and so did the search for another solution.

Fresno's structure is 108 feet long and 15 feet high. Albany's is higher—and heftier—because Albany has something that Fresno does not—heavy snow. "We improved on the California design by adding substantial cabling and wire mesh to sustain higher winds," says airport planner Steve Aichetta. Ultimately, engine noise was cut in half for a mere $188,000.

—Laura Lee

And the Space Probe Is...

This June, one team of scientists (or maybe even two) will learn that their proposal will become NASA's next faster, better, cheaper Discovery-class space probe.

"You go through a series of emotions," says Cornell astronomer Joseph Veverka, who got the call in 1997 for his team's Contour, which will be launched in 2002 to analyze three comets of different ages. "You're tremendously elated and excited at first. And then relieved, because a large group of people have spent a lot of time working on this. And then, well, you realize there's a lot of work ahead."

The 1999 winner will be NASA's seventh Discovery probe (not to be confused with the space shuttle of the same name). Originally the agency generated its own Discovery concepts, but in 1994, looking for fresh ideas, it opted for open auditions, as long as the proposals meshed with its lofty Strategic Mission (to learn more about "the origin, evolution and destiny of the Cosmos and life") and did so on a budget of up to $299 million ("And if it's that high it probably won't be selected," says Veverka). Now the call for Discovery ideas goes out every 18 months. The proposals are reviewed by two teams of scientists and whittled down to a handful.

Five finalists were selected from the 29 submitted late last year: a probe to image Mercury, another to investigate the atmosphere of Venus, one to sample Martian moons, a probe to study Jupiter's interior from a polar orbit, and one that would blast a 1,100-pound projectile to the interior of a comet.

The losers get a personal phone call. "At the moment they're not a very happy camper," says Wayne Richie, Discovery acquisition manager. "But then most are anxious for the next [call for proposals] to come out." In fact Veverka's Contour was one that didn't make the cut in 1996. "It was ranked in the top ten," Veverka says, "so while we were disappointed, we felt that by being a little more clever the next time we had a good chance."

—Phil Scott

Airports: Back to Basics?

More than three million passengers take to the air each day in the United States, often paying no attention to the airports they pass through. "Yet these spaces that we rush to reach—and hasten to exit—are arguably among the most significant buildings in the urban environment today," Steven Reiss told a symposium entitled Aviation and the American City. Reiss, the moderator of the daylong event, is not one of those who ignore airports. He's been designing them since 1971, currently as executive vice president of the Alexandria, Virginia firm HNTB.

The symposium was held last February in a building constructed two decades before the Wrights flew at Kitty Hawk. Yet with its vast interior space, Washington, D.C.'s National Building

Museum gives an impression similar to that of some of the most imposing modern airports. The museum's soaring 15-story Great Hall brings to mind what Reiss called today's "cathedrals of air transport."

Airports were not always so impressive. In the 1920s, said David Brodherson, a design historian at Hunter College in New York City, the "depot hangar" combined passenger facilities, airline office, and hangar in one structure. In the 1930s, some airports were decorated with aircraft silhouettes and other "exquisite surface detail referring to the function as an aerial gateway," he said. But in more recent airports, designers have ignored such images. Brodherson also noted the loss of great terminals, destroyed because of intense pressure for change at airports, and he called for preservation of other such structures that are threatened with demolition.

Marilyn Jordan Taylor, a partner at the international firm Skidmore Owings & Merrill, proposed design objectives for airports that parallel the needs of cities in general. One is the need to retain clear identity. Like cities overall, she said, "too many airports are the same. How many times have you been through an airport and hardly remembered where you were? The individuality of airports [should be] as distinctive...as the cities they serve."

HNTB CORP.

Is this HNTB plan for Salt Lake City the airport of the future?

U.S. Congressman Earl Blumenauer of Oregon raised other concerns. An advocate of constructing communities that are more livable, his interests are land use, community health and safety, environmental protection, and economic security. Blumenauer noted that airport development creates jobs and stimulates commerce, but also increases pollution, noise, and air and ground traffic. Like Taylor, he advocated integrating airports into a multi-mode transportation system, including high-speed ground transport. "We get an absolute zero in this country," he said, "compared to what I have seen in most other parts of the world, in making the airport into a fully functioning entity [with] ground access and inter-city connection."

Blumenauer also lamented "the voracious appetite for large tracts of land" dedicated to airports. One new approach

to land usage was reflected in the vision of an airport of the future presented by Moshe Safdie, an airport architect with current projects in Toronto and Tel Aviv. who said a "hard and unsentimental look" at an airport shows that it is simply a transfer point from aircraft to ground transport or from one airplane to another. Perhaps a transfer point "needs no building at all. Or if it does...perhaps it needs a whole series of dispersed, disconnected buildings."

Safdie pointed out that most of today's airports are unacceptably congested at places such as those where cars drop off or pick up passengers and where people connect from parking facilities to the terminal. "Basically, we're unable to deal with the confluence of all these traffic points," he said, "because we're dealing with it at one point." Safdie advocated decentralization with an automated people mover—a horizontal elevator that would link dispersed facilities. "We've gone through a whole era where airport design was focused on the building as a kind of architectural experience that transcends the transportation role of the airport," he said. "We should now return to first principles and think of how to get from point A to point B as painlessly as possible."

—Lester A. Reingold

Home Vrrroom

We all did it as kids. We held yellow pencils like joysticks and pulled back into big, glorious loops; we lined up our Schwinns' front fenders on fleeing enemy Buicks and let blast devastating rounds of .50-caliber *eh-eh-eh-eh-eh-eh-eh*s just as they turned on Main Street to escape. We were aces all.

But when did the wild blue adventures of our childhood cease? Typically when we reached our teens, the time when everything is reassessed and all childish things are abandoned.

And that's why Clayton Carkin's ejection seat still gets so much use.

Carkin—that's Mr. Carkin to his charges—is a sixth grade homeroom and science teacher at Freeport, Maine Middle School. He's also an enthusiastic pilot. He's discovered that his students, mostly 11-year-olds, are still eager make-believers, and that aviation seems to help stimulate their minds.

A part of every school day at Freeport is devoted to reading. Years ago it occurred to Carkin that aviation paraphernalia might inspire his youngsters. He put out the word he was looking for, well, stuff. As luck would have it, a friend who had helped restore a buddy's aircraft was given an ejection seat from a Mohawk as payment for his labors. He in turn gave it to Carkin, who installed it in his classroom. The thing was an instant hit. His homeroom kids loved sitting on the thing as they did their daily reading. More gear started arriving by bits and pieces—a flightsuit, goggles, a power quadrant, a joystick. Carkin used all of it.

"We've got a real mongrel aircraft here," he says. "The throttle quadrant comes from an A-10, the instrument panel from a Vultee Vibrator, and the seat's from a Mohawk, but the kids could care less. For them, it could all come from an F-15 Eagle."

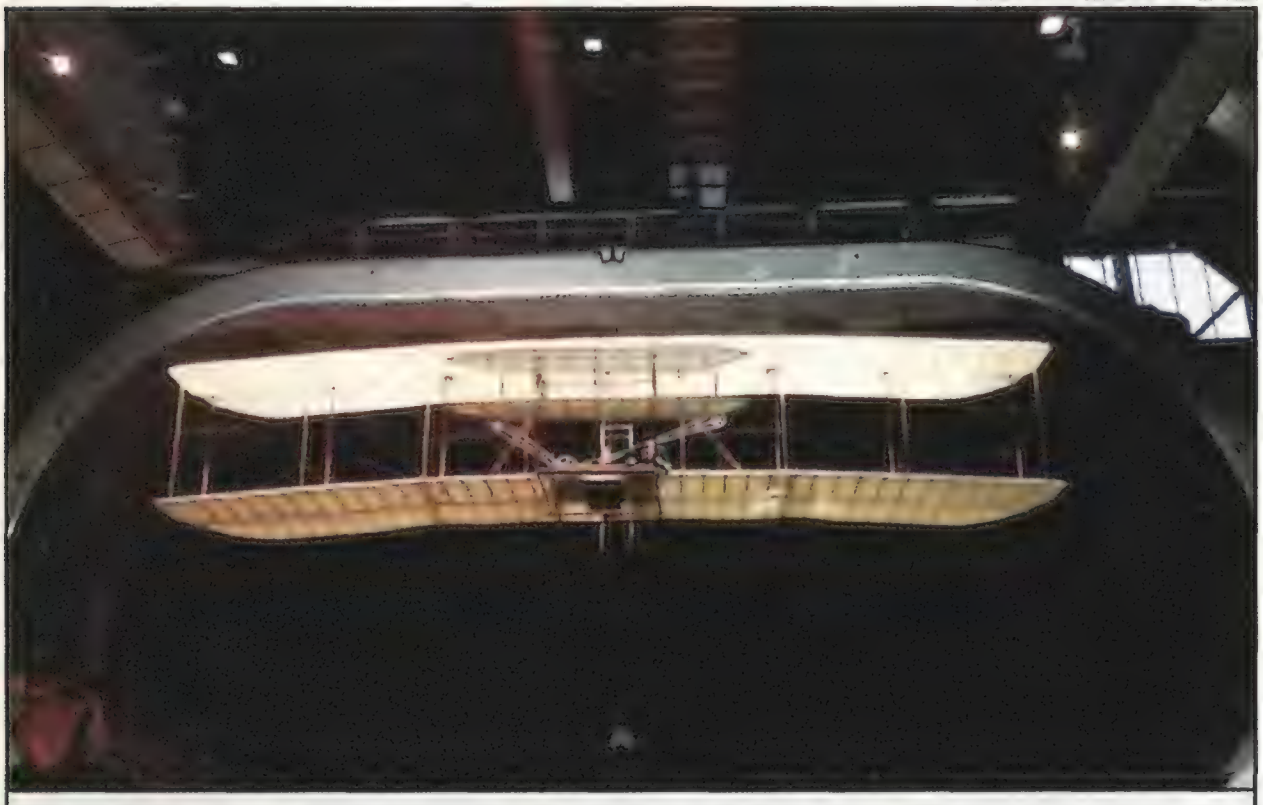
Carkin also conducts a month-long aviation unit for his science kids that includes a model fly-off. And for those students with the interest and grades, he arranges familiarization flights with local pilots.

The bootstrap program is going well and Carkin wants to expand it. He wants another ejection seat so he can accommodate twice the number of kids. And he's got his "gimme" sign up for any other aeronautical castoffs that might be buried in attics, basements, and garages. Whatever it is—busted altimeter, dead automatic direction finder, discarded EA-6B, flattened Mae West, or permanently stuck mike—he'll take it gladly. The kids' imaginations will get the stuff working in no time.

"Eleven-year-olds love this stuff," he observes. "Sixth graders are still at an age when they can dream and pretend to be pilots and fly. The ugly head of adolescence has not quite appeared—that's when it's 'not cool' to be seen by their peers wearing pilot clothing and sitting in the seat. But this will be the last chance for several years before it's okay to do these things again."

—William A. Garvey

NASA AMES RESEARCH CENTER



A case of tunnel vision led volunteers from the Los Angeles chapter of the American Institute of Aeronautics and Astronautics to NASA's Ames Research Center in California with a full-scale replica of the 1903 Wright Flyer. *Tests performed in the 40- by 80-foot wind tunnel last March provided data on Reynolds numbers, wing warping, and power effects that the AIAA team will apply to another replica—this one modified to tame the highly unstable design characteristics—that will fly on December 17, 2003, the 100th anniversary of the Wrights' flight.*

Ace in a Day

Aviation buffs like to compile lists. One of the most exclusive contains the names of 92 Americans officially credited with becoming aces—destroying five or more enemy aircraft—in a single day.

Make that 93. On September 28, 1944, Second Lieutenant John Wainwright of the 404th Fighter Group was flying his P-47 Thunderbolt over Holland. His squadron leader was bounced by three Luftwaffe fighters. Wainwright went to the rescue, "without support and completely disregarding the heavy odds against him," in the words of his subsequent citation for the Distinguished Service Cross.

One German aircraft exploded, throwing his Thunderbolt into a spin. Recovering, Wainright went on to claim five other enemy aircraft, including two that collided while trying to avoid his fire. Six in a day! In addition to the DSC—the Army's second highest award for valor—Wainwright got the Silver Star and Distinguished Flying Cross.

UPDATE

Departures

A stroke claimed the life of airline executive Martin R. Shugrue Jr. at age 58 last March. As the appointed trustee of Eastern Airlines, Shugrue heroically attempted to save the airline after a judge took chairman Frank Lorenzo out of the equation ("Life After Eastern," Dec. 1993/Jan. 1994) but was forced to succumb to overwhelming losses in 1991. He next tried to resuscitate Pan American Airways, which he had also tried to save in the 1980s, but that company filed for bankruptcy in 1998.

J. Leland Atwood, a North American and Rockwell engineer and executive present at the creation of such pivotal craft as the P-51, F-86, F-100, X-15, XB-70, B-1,and the space shuttle, died last March at age 94 in Los Angeles ("Who Made the Mustang?," Aug./Sept. 1996). Under Atwood's leadership, North American and Rockwell were awarded three Collier trophies, for the F-100, X-15, and B-1.

Forty years later, Robert Huddleston of the 404th came across *U.S. Air Force Historical Study No. 85*, listing enemy aircraft kills credited to Army Air Forces pilots during World War II. To his astonishment, Wainwright's victories were shown as "destroyed—unconfirmed."

"This is ridiculous," Huddleston thought. "There was no doubt in anybody's mind that [the victories were] confirmed." Wainwright, after all, was the 404th's first and only ace.

In the language of the day, it was a snafu. To confirm the victories, an original copy of the DSC citation was needed—and none seemed to exist, though the citation was signed by General Carl Spaatz himself, commander of the Army Air Forces in Europe. In time, however, another 404th veteran located a copy in his files, and last October the record was corrected.

Wainwright never knew he'd fallen through the cracks of aviation history. He was killed in July 1945 while taking off from Stuttgart, Germany, after the European war had ended. He was 21 years old.

—Daniel Ford

Musical Airplanes

Where can you go to see the prototype of Boeing's 707 airliner, an SR-71 Blackbird spyplane, the space shuttle *Enterprise*, and the B-29 *Enola Gay*? Nowhere…yet. But the National Air and Space Museum is busy planning a new home for these and almost 300 other air- and spacecraft, some of which have never been publicly displayed. Named the Dulles Center, it should be open to the public by December 2003.

The Dulles Center will be located on the south edge of Washington Dulles International Airport, near the intersection of Routes 28 and 50, close to the border of Virginia's Fairfax and Loudoun counties. Designing the facility has been a massive undertaking—plans for the buildings alone are spread out over 1,400 pages of drawings, each one of which must be carefully reviewed. Every detail has been included, even the proverbial kitchen sink.

Deciding how to position the wide variety of craft inside the buildings has been just about as intense. In March 1998, a group of curators from the aeronautics and the space history departments spent three days playing with tiny Plexiglas cutouts representing various artifacts, which were color-coded according to their location in the display hall. We would manipulate the Plexiglas pieces in the morning, then William Jacobs, a designer from the Museum's exhibit department, would record our changes on a computerized layout. As the collections division representative, I worked with the curators, and we had to consider everything. For example, there will be two levels of hanging aircraft. Each truss, or building support, can hold up to 20,000 pounds. This is roughly what three lightweight World War II fighters displayed side by side would weigh. In planning which fighters go where, we had to make sure that the aircraft didn't overload the truss or that the airplane hanging in the middle was not obscured from view.

ERIC LONG (2)

Aeronautics curators Russ Lee and Dorothy Cochrane and exhibits designer William Jacobs (at computer) are among the many Museum personnel who have spent more than three years coming up with a workable layout for the dozens of aircraft that will be displayed at the hangar-like Dulles Center.

The hanging aircraft presented other troubles. The display area at Dulles is divided into two hangar-type buildings. We initially thought about hanging a formation of nine World War II fighters and trainers in the north end of our aircraft building. Because of its popularity, we placed the Museum's Curtiss P-40 Warhawk in a prime viewing spot, at the front of the pack. This pleased everybody—until we realized that the aircraft hanging directly behind the P-40 was the Museum's Nakajima Ki-43 Oscar, the same type of aircraft that Don Lopez, the Museum's deputy director, had shot down in his first aerial victory—while flying a P-40! After exploring other placements, the P-40 and Ki-43 ended up side by side.

Aircraft on the floor are divided into two major groups: military and civilian. We had long planned on having certain aircraft, such as the *Enola Gay*, the SR-71, and the Boeing 707 "Dash

80" prototype, displayed with smaller aircraft around them. The Dulles Center exhibit areas will be like big hangars, without the individual galleries of the Museum downtown, so we had to try to arrange aircraft thematically without relying on walls to group them—a real challenge with our military collection. To do this, we arranged the aircraft so that the walkways in between created distinct groupings: early flight, World War II, air transportation, racing, Vietnam, and so on. With these areas established, our exhibits department began laying out a series of kiosks among the aircraft to further define themes and provide visitors with more information.

In laying out the floor-mounted aircraft, we strived to maintain the sense of spaciousness characteristic of a hangar. We designed walkways wide enough to accommodate groups of browsing visitors (as well as the cranes and platform lifts we will use to maintain the hanging aircraft). We also had to ensure that aircraft with low wings, such as our Lockheed T-33, didn't protrude into the walkways. So we arranged the aircraft with higher wings, such as the Sikorsky JRS-1, closer to the aisles. Their wings may stick out a little, but they are high enough to walk under.

On the civilian end of the collection spectrum, the Dulles Center will have such notable airplanes as the Lockheed Vega *Winnie Mae*, a Boeing 307, and the second Pitts Special built—Betty Skelton's *Little Stinker* (see "Vintage Skunk," In the Museum, Aug./Sept. 1998). While our military aircraft fall neatly into time periods, we decided to group our civil aircraft by purpose, such as business or racing. Disparities in aircraft size, however, occasionally forced us to integrate two or more groups on the display floor: Our air transportation display will include aircraft ranging from the relatively small Junkers Ju-52 to the much larger Boeing 707, but not having any smaller airliners to tuck under their wings, we will use the space to exhibit racing airplanes and flying cars.

Many of the aircraft in our collection need either partial or full restoration, another factor we had to consider in arranging them. Because we believe our visitors will enjoy seeing unrestored aircraft, such as the Vought V-173 "Flying Pancake," we want to put as many of them on display as possible. They'll be positioned near the large doors at each end of the building, so they can be easily removed and taken to the Dulles Center's restoration shop.

There, visitors will be able to view restorations in progress from a second-level observation deck. The restoration shop will be state of the art and will feature a 10-ton-capacity bridge crane for working with our larger aircraft. Although we haven't selected the first restoration projects to be conducted at Dulles, aircraft such as the Boeing B-17D *Swoose* and the Grumman TBF Avenger are likely candidates.

On the space side of things, visitors to our space hangar will be able to come nose to nose with the space shuttle *Enterprise*, the Skylab multiple docking adapter, an Apollo command module boilerplate, and an amazing collection of engines, satellites, and rockets. This area will give visitors a broader perspective on spaceflight than they are able to get at the Museum downtown. The building will also allow visitors a closer inspection of the artifacts that have made space exploration possible, such as Spacelab, our latest acquisition. Having served as a science platform for shuttle-based research for more than 15 years, Spacelab will be displayed in front of the *Enterprise*.

Like many of you, I can't wait for the Center to be built. I've been working on it, after all, for over three years. Still, we have a long road ahead. The Museum will have to privately raise $130 million of the construction cost. Artifacts must still be bar-coded for tracking purposes, computerized inventories have to be updated, and dozens of aircraft will need to be touched up and put on moveable dollies. Even so, by the time you read this, the design of the buildings will be complete. See you there.

—Scott Wirz

On April 7, balloonists Bertrand Piccard, a Swiss psychiatrist (left), and Brian Jones, a British aeronaut, visited the National Air and Space Museum to receive a trophy and a $1 million check from Anheuser-Busch to honor their achievement in making the first nonstop around-the-world balloon flight. During the press conference that followed, the two men spoke with remarkable grace about their 20-day journey, which began in Switzerland and ended in Egypt on March 21. "We didn't have to overcome nature, we had to harmonize with it," said Piccard of the 26,542-mile flight, in which they traveled at the mercy of Earth's winds. Their aircraft, the Breitling Orbiter 3, will become part of the Museum's permanent collection in September.

Museum Calendar

Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700; TTY (202) 357-1729.

June 23 Exploring Space Lecture: "After the Big Bang." Robert W. Wilson, a senior scientist at the Smithsonian Astrophysical Observatory, will discuss his discovery of cosmic microwave background radiation, the most vital evidence yet that the universe originated from a Big Bang. Wilson will end his presentation with a brief history of the universe, starting at the tender age of a microsecond. Einstein Planetarium, 7:30 p.m.

June 26 Monthly Star Lecture: "Landing on the Moon." Bob Craddock, a geologist at the National Air and Space Museum, will talk about the effort that went into selecting safe and scientifically important landing sites for the six lunar landings. Einstein Planetarium, 6 p.m.

National Air and Space Society Lecture: Captain Eugene A. Cernan. In December 1972, Cernan served as the commander of Apollo 17, the last manned lunar mission of the Apollo program. Langley Theater, 8 p.m. To purchase tickets ($10 for NASS and Smithsonian Contributing Members, $15 for non-members), call (202) 357-3762.

June 26 & 27 Family Activity: "You Can Fly." Co-sponsored by *Air & Space/Smithsonian* magazine, this event will educate visitors about the variety of programs that offer flying lessons. Representatives from aviation organizations will share information and answer questions. Milestones of Flight Gallery, 9:30 a.m. to 6 p.m.

National Air and Space Society

As a Founder Member you can help support the most significant effort in the National Air and Space Museum's history: the new Dulles Center, to be built at Washington Dulles International Airport. For information, call (202) 357-3762 or write to: The National Air and Space Society, NASM, Room 3608, MRC-310, Smithsonian Institution, Washington, DC 20560; e-mail: nass@sivm.si.edu

Car Talk

In 1963, Dale Reed and other engineers at NASA's Dryden Flight Research Center in California's Mojave Desert experimented with lifting body designs for a spacecraft that could land like an airplane. The M2-F1 was the first full-scale craft the group tested.

Dick Eldredge and I had designed the M2-F1 lifting body to weigh 600 pounds. However, like most prototypes, it had gained weight during fabrication and now weighed 1,000 pounds. From Ken Iliff's calculations of the M2-F1's tow force and liftoff speed, we knew that to do taxi tests before the wind tunnel tests, we needed a ground-tow vehicle with greater power and speed than any NASA truck or van could provide. We needed a vehicle that could tow the M2-F1 at 100 mph and, at that speed, handle the 400-pound pull needed to keep the 1,000-pound lifting body airborne. We ended up with what was probably the only government-owned hot rod convertible.

Working in operations at the NASA Flight Research Center was Walter "Whitey" Whiteside, a veteran dirt-bike rider and expert hot-rodder. Whitey volunteered to find, buy, modify, test, maintain, and drive the high-powered ground-tow vehicle we needed.

The best choice seemed to be the Pontiac Catalina, the big winner at the 1962 Bonneville Salt Flats time trials in Utah. Whitey put through a special factory order for a convertible with a four-barrel carburetor and four-speed stick shift. Flight Research Center engineers equipped the Pontiac with a tow rig and airspeed measuring equipment.

Whitey took the car to Bill Straup's renowned hot rod shop near Long Beach, where the straight-pipe Pontiac was modified to run a consistent 140 mph. There, technicians also applied their hot rod wizardry, producing maximum torque at 100 mph. They added a special gearbox, with transmission gear ratios significantly different from those that had helped the Catalina win at the Salt Flats, enabling the Pontiac to tow the 1,000-pound M2-F1 to 110 mph in 30 seconds. The 421-cubic-inch souped-up engine got about four miles to the gallon.

Whitey had roll bars, radios, and intercoms installed. The front passenger bucket seat was reversed and the back seat was removed, replaced by another bucket seat so that a second observer could sit sideways. Of course, the Pontiac had to have government plates, the NASA logo on both sides, and racing stripes. To keep anyone from thinking the car was a personal toy paid for with government funds, the hood and trunk were spray-painted high-visibility yellow so the convertible looked like any other flightline vehicle—well, almost.

When the car was finished at the hot rod shop, Whitey drove it back to the Flight Research Center. Once he got on the highway across the desert, he found it difficult to hold back. But he realized he would get his chance later to open up on the dry lakebed, so he was being particularly careful to hold the speed to the posted limit when he saw in the rearview mirror the red light of a California Highway Patrol vehicle.

Pulling over to the side of the highway, Whitey wondered what he'd done wrong. It turned out that the officer was merely curious, having never before seen a government-owned convertible, especially one with a souped-up engine. After he'd taken a careful look and Whitey had explained how the car would be used, the officer drove away, shaking his head in amazement.

The Pontiac also caught the eye of other drivers whenever Whitey took it out on little-traveled desert highways northeast of Edwards—often into Nevada with its anything-goes speed limit—to calibrate the speedometer, as is typically done with research airplanes. During one such venture, he headed out with one of the base's pilots. As the Pontiac rumbled along, exhaust system roaring as the speedometer moved above 100 mph, Whitey glanced at the pilot to find him ashen-faced with fear and trying to disappear into the seat.

We were still divided on which basic roll control scheme to use on the M2-F1. Bertha Ryan, Harriet Smith, and pilot Milt Thompson backed their simulation results, saying the rudders would give the best control. Ken Iliff and Larry Taylor countered that their mathematical calculations showed that using the rudders would lead to pilot-induced oscillation. I thought that the outboard elevon surfaces simply looked right for roll control, and I believed that rudders were meant for controlling yaw, not roll. In the end, out of enormous respect for Thompson's skills, we agreed to use the scheme he preferred, with the pilot's stick hooked to the rudders for roll control. We could reconfigure to the other scheme if that one didn't work.

We had no official approval to flight-test or even taxi-test the M2-F1. But sitting in the cockpit, Thompson reasoned that perhaps it wouldn't really be flying if we just lifted it off the lakebed a couple of inches. Boosting our confidence was data from earlier small-scale wind tunnel tests. Center director Paul Bikle said to go for it, but carefully.

We began towing it behind the car at low speed on its landing gear, working up to the nose liftoff speed of 60 mph. During these runs, Thompson became familiar with the cockpit and with visibility out the top, through the nose window at his feet, and out the side window level with his feet, odd locations necessitated by the anticipated high angle of attack.

After a week of cautious towings, Thompson was ready to try a liftoff. Following his radioed directions, Whitey took the Pontiac and the M2-F1 up to 86 mph, the 1,000-foot towline giving Thompson plenty of maneuvering room.

Slowly Thompson brought the nose of the little lifting body up until the M2-F1 got light on its wheels. Then something totally unexpected happened. The M2-F1 began bouncing from right to left.

Thompson stopped the bounce by lowering the nose and putting weight back on the wheels. Several times he again brought the nose up until the M2-F1 was light on its wheels, and each time the vehicle reacted the same way.

Later, in our little debriefing room, Thompson said he felt that if he had lifted the M2-F1 off its wheels, it would have rolled upside down. He felt it had something to do with the landing gear and wondered if there was enough damping in the oleo-type shock system. Ken Iliff suggested that maybe Thompson was feeding the roll motions with the stick or rudder pedals. Absolutely not, Thompson maintained, adding that during liftoff he had made sure he wasn't making roll or yaw control inputs.

We planned to get a little data by installing an instrumentation system in the M2-F1 after wind tunnel testing. Before that, however, using a ground-chase vehicle, we made 16-mm movies from the rear of the M2-F1, having painted reference stripes on the rudders so we could determine their positions. The movies showed that during liftoff the rudders were moving back and forth. When Thompson saw the footage, he concluded that slop—looseness or play—and inertial weights in the rudder system—not the pilot—were causing the rudder motion.

Larry Taylor suggested we construct data from the movie frames. Using a stop-frame projector, we could determine the M2-F1's rudder positions and body roll angle by the craft's position against the horizon in the background. We projected the filmed images of the M2-F1 onto a large sheet of paper on the wall, then measured the roll angle and rudder positions in each frame with a protractor. Using the frame rate of the projector, we then produced plots of the rudder movement and roll angle.

In the hangar, we examined the rudder control system, finding it exceptionally stiff. No way could the rudders be moved without moving the pilot's stick. We examined the weight distribution of the rudder system, looking for ways that inertia could cause the rudders to move during vehicle roll.

Iliff compared the phase relationships between rudder position and roll angle. The control motions were typical of what a pilot would put in to combat roll oscillations. Finally, Taylor and Iliff stated they had no doubt that, knowingly or unknowingly, the pilot was working to combat the roll and that continuing to try to fly the M2-F1 with the control system driving the rudders from the pilot's stick would, during roll control, lead to loss of control of the vehicle. They insisted that the current control system be abandoned and the other control system—driving the elevons from the pilot's stick—be hooked up for the next series of car-tow tests.

We had only one week left for these tests before wind tunnel tests at NASA's Ames Center. Given the strength of Taylor and Iliff's conviction about the control systems, I didn't want to waste time on more car-tow tests with the original control system, so I asked Vic Horton to change the control system as Taylor and Iliff had recommended.

After I made this decision, the group lost some of its harmony and camaraderie. Tension built during this disagreement as group members began to realize that a pilot's life could be at stake. Thompson was such a personable guy and worked so closely with us that strong emotions started emerging whenever critical decisions had to be made. I began to think it was better for the research pilot to be more distant from the project people.

Thompson had been on a trip, and when he returned, I told him about the changes in the roll control system. He accepted them but still thought that the problem was caused by the landing gear and that, when the new control hookup didn't solve the problem, we could go back to the original hookup.

We again hooked up the M2-F1 to the Pontiac, and, with Whitey at the wheel, off they charged across the lakebed. Cautiously, Thompson rotated the nose of the M2-F1 until there was very little weight left on the wheels. He continued rotating the nose until the wheels were about three inches above the lakebed. The M2-F1 remained steady as a rock. We made another run, this time to an altitude of three feet. Thompson was gently maneuvering the M2-F1 right and left behind the Pontiac, but the lifting body showed no tendency to oscillate.

By now, Whitey had had Mickey Thompson's shop replace the Pontiac's rear tires with drag slicks, a change that increased the car's towing speed to 110 mph. Normally, racers use the wide, high-traction, treadless tires known as "slicks" because in the very short race known as a "drag," torque from the drive train to the lower gears is greatest at the start, when tire slippage is most likely to occur. Our experience was exactly the opposite, with maximum drag reached at the high-speed end of a tow. Without the slicks, at about 90 mph the tires on the Pontiac would start slipping. Adding the drag slicks increased the towing speed enough to allow Thompson to climb to 20 feet in the M2-F1, release the towline, and get about 10 seconds of free flight before landing.

The new control system handled well in flight, both on and off tow, and Thompson seemed happy with it. No one ever suggested we go back to the original design. And never again did we discuss control rigging within the group, other than how to reduce stick forces with aft stick positions.

While the Pontiac was a prominent feature of the M2-F1 adventure, it in no way resembled the usual flightline vehicle. According to Whitey, whenever someone from NASA headquarters was visiting the Flight Research Center, Paul Bikle would slip away to phone him, telling him to hide the car. Whitey would pull the Pontiac behind a shed and throw a cover over it until the visitor left.

Near the end of 1963, the Pontiac was shipped to NASA's Langley Research Center in Virginia and used in tests at Wallops Island. Some at the Flight Research Center were sorry to see it go. In *X-Press*, the NASA newspaper at Edwards Air Force Base, one writer lamented: "No longer can we drive along the lakebed and pass the airplanes in flight."

Adapted from Wingless Flight: The Lifting Body Story *by Dale Reed with Darlene Lister. NASA 1997. $25. Available from Government Printing Office, Superintendent of Documents, MS SSOP, Washington, DC 20402.*

Workers at Dryden Flight Research Center pushed the envelope in a souped-up Pontiac that helped get the lifting body program off the ground.

NASA

The Little Engines That Could

Engines have voices, voices as distinctive as the Three Tenors, though some are baritones, others *castrati*. Until a motorhead named Wallace Warner came along, there was no way to sample the Doppler moan of a Merlin, the tin-cans-in-a-dryer chutter of a loping Pratt & Whitney, or the potato-potato-potato idle of a Harley vee twin other than to be behind or atop one, or listening to a soundtrack. Warner and his son Scott build and sell exact-replica, limited-edition aviation and automotive engines in one-quarter scale. They're small enough to use as paperweights, big enough to show every part in stunning detail, artful enough to grace coffee tables or boardrooms, and, at $3,800 to $6,500, expensive enough to never be called "model-airplane engines."

And they run. Boy, do they run. Each engine (with one exception) comes with an optional stand that hides a battery-powered starter motor and ignition-spark source. Put the mill on your desk, tell your secretary to hold all calls, prime, choke, crank...and suddenly you're enveloped in the sound of a Gnome rotary-powered Nieuport warming up for a dawn patrol, a Harley track bike sideways on the dirt of Ascot, or a Jenny beating its way into the air behind a Curtiss OX-5. In truth, Warner's OX-5 requires a little more than a desktop. Since it needs to swing a two-foot wooden propeller with lethal metal leading edges, it's best bolted to something substantial—maybe a pickup truck. The OX-5 V8—Warner's most complex engine yet—includes a perfect miniature Winfield carburetor, all of the exposed valve gear, wet-sump pressure lubrication, a tiny working oil-level indicator on the pan that reads in gallons, and the odd X-shaped brass hold-down straps atop each cylinder head. To keep the heads from blowing off? "No, *after* they've blown off, to keep 'em from flying back into the cockpit," Warner explains. "The OX-5 was not a good engine."

COURTESY REPLICA ENGINES (3)

CURTISS OX-5

The nine-cylinder Gnome Monosoupape, at the press of a running-stand button, fills the air with the distinctive aroma of castor oil. Just like a full-size rotary engine, its crankshaft is stationary, bolted to the miniature firewall. The engine itself rotates around the crank at a dizzying 2,400 rpm and doesn't need a prop to run, since the engine itself is a big flywheel. What it does need is the running stand's arch of Plexiglas to trap the spray of oil flung off by the whirling cylinders. Since rotaries have no throttle and run only wide open or coasting, the sound that's produced as Scott Warner blips the ignition cutoff is authentic and inimitable: WAAAHHHsssssssss WAAAHsssssssss.

Warner has sold 60 Gnomes (at $3,800 each, with the running stand an extra $1,300) and, as he did with the OX-5, will make only 100. "Most people who buy these engines collect them," he says. "They own one of each, and when a new one comes along they add it to the collection." Besides the Gnome and Curtiss aircraft engines, Warner builds a Ford V8 60 and Model 97 Offenhauser, both midget-racer engines, and a 1937 Harley-Davidson Knucklehead. The Harley vee twin is his biggest edition: a planned 750. "Harley said we'd probably sell one to every dealer, and there are 750 Harley dealers. We got something like two orders from them," Warner laughs. "They're young guys, and they don't even know what they're looking at when you show 'em a Knucklehead."

Nobody has yet put one of Warner's aircraft engines into a flying model, though one customer has mounted a Gnome in his quarter-scale Fokker Eindecker and taxied it. "But it's a wing-warping design, and with the torque of that rotary engine, I don't think you'd dare try to fly it," Warner avers. (Word has it that Eindecker owner Fred Coleman will hazard a flight at Old Rhinebeck Aerodrome in New York in September.)

Typically, the people who buy his engines are not particularly mechanically inclined, Warner admits. But there's at least one exception. "We did have one lady in California who bought an engine, but she wanted it all in pieces," Warner's wife Nancy recalls. "She wanted it for her boyfriend to assemble, and she was sure he could figure it out. We never heard from her again, so I guess he did."

—Stephan Wilkinson

HARLEY-DAVIDSON KNUCKLEHEAD

GNOME ROTARY

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National Air and Space Museum

During World War II, the United States assembled the largest air armada ever known. More than 140,000 fighters were built, and bomber production rose from 5,500 a year in 1939 to 5,500 a month in 1942.

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Mustang Mania

The staying power of the P-51 proves that a thing of beauty is a joy forever, if you can keep getting parts.

by Linda Shiner

Early in the first week of April, Tim Shea, the manager of a small airport just south of Orlando, Florida, got an e-mail from a friend and airport manager at Falcon Field, near Mesa, Arizona. "Tim, 12 Mustangs just came through here bound for your place," he said. "What's going on?"

Shea's delighted answer was that the aircraft were coming east for the historic Gathering of Mustangs and Legends, a fly-in of restored P-51s and a celebration of the legendary pilots who flew them. The vintage fighters trickled in until by Saturday, April 10, a total of 67 Mustangs—about half of all the ones still flying in the world—were parked at the airport in Kissimmee. They were invited by Stallion 51 Corporation, a small operation offering orientation flights and checkout training. Stallion 51's director, Lee Lauderback, organized two days of seminars on handling and maintenance, with lectures on such topics as "gyroscopic principles and propeller performance." The pilots came, first, to be a part of the largest assembly of Mustangs since the Korean war, second, to check out everybody else's Mustang, and third, to swap stories and share information on things like where to find dwindling parts.

After two days of schoolwork, there was a day for fun: The airport was open to the public, and the participants simply came out to the airport to stand by their airplanes, listen to war stories from vets who flew the aircraft, and shoot the breeze with each other and 12 of the most famous Mustang pilots of all time, including sound barrier breaker and World War II ace Chuck Yeager and airshow great Bob Hoover. Every few minutes a pilot would crank up a big Merlin and take his prize up for a quick flight around the airport.

CAROLINE SHEEN

But those who came to the public day of the Mustang gathering expecting an airshow—and there were a few among the throng who wondered when the aerobatics would start—were disappointed. "This is not an airshow," announcer Sandy Sanders admonished periodically (a disclaimer made somewhat unnecessary by the prolonged absence of aircraft in the sky). This, instead, was more of a class reunion.

Most of the Mustang owners were coming back to Florida as alumni of Lauderback's flight training program. Since 1987, about 75 pilots have checked out in Lauderback's dual-control TF-51, *Crazy Horse*. "If you fly a Mustang, I probably trained you," he says. Novices can get a brief (but expensive) orientation and walk on the wild side. The more serious—and wealthier—trainees learn how, in the words of one, "to do everything I could do in a Mustang and everything I'd never want to." The length and cost of the flight training vary greatly, depending on the student's proficiency. Training includes ground school and practice in takeoffs, landings, stalls, and spins.

The training is not a Federal Aviation Administration requirement. Anybody with a pilot's license that has high-performance and tailwheel endorsements can hop in a Mustang (the non-racer variety) and go; anybody who has taken off and landed the airplane three times can take a passenger along. But according to many pilots at the gathering, if you've just purchased a Mustang and want to buy insurance, your underwriter is likely to suggest a visit to Stallion 51. The training lasts "until Lee thinks you're qualified," says Dick

Lee Lauderback (above) and his Mustang fly-in protected the Sunshine State from the Luftwaffe, if only for two days.

PAUL BOWEN


"Ole Yeller"
"Bob"
Heaven
Shangri-La
Donna-mite
FF-197
U.S. AIR FORCE
472197
472934
413586
COLORADO
VF
T
C5

Thurman of Louisville, Kentucky, who was there with *Slender, Tender, and Tall*, a TF-51 rebuilt by Lauderback's twin brothers, who run Stallion 51 Maintenance Operations.

The trick to flying a Mustang is "you have to think five minutes in front of it," says Steven Coutches, an American Airlines captain and one of a minority at the event whom Lauderback did not train. Coutches learned to handle a Mustang by riding along in the back seat of his father's restored H model from the time he was nine until Dad let him try the controls. He restored and now flies a P-51D with an extended tail, owned by his mother, Frances. "When you fly jets for a living, you're already thinking at that speed," he says. "You have to have the plan before it happens." Thinking ahead, Coutches briefed the controllers and emergency crews at his local airport on his flight plan before he took the restored D model up for the first time. ("I told them where I wanted the fire trucks," he says.)

Michael, the elder Coutches, is from a different school. He bought his first batch of Mustangs—six of them—in 1957, paying $1,000 for each at an Air Materiel Command auction. The next day he flew one from the base in Sacramento to his home in Hayward, California. "I read the handbook," Coutches says, "and it's a pretty good handbook." He has bought and sold more than 30 Mustangs.

Michael Coutches is an exceptional pilot; there's hardly another around today who would attempt to fly a Mustang after spending one night reading the handbook. But the need for proper training has been a hard-learned lesson in the warbird community. According to Federal Aviation Administration records, 16 people have been killed in Mustangs since 1983. "We lost two in Europe last year," says Anders Saether, a Mustang owner from Norway who is a graduate of the Stallion 51 training program.

Besides the human tragedy, Lauderback points out, accidents have reduced by 10 percent the number of P-51s flying, "which is totally unacceptable," he says. So Lauderback started the flight training program in part as an act of preservation.

One of the grave dangers posed by the Mustang is its behavior during an accelerated stall—a loss of lift caused by disturbed airflow over the wing in a high-G maneuver like a tight turn. The Mustang can react violently, snapping into a roll and sometimes flipping over on its back. "It virtually gives you no warning," says Saether.

At Stallion 51, pilots get sensitivity training: They learn to notice the subtle vibration in the stick that presages an accelerated stall. They also learn the procedures for recovering. Perhaps the hardest part of recovery is that the pilot must be patient enough (and have enough altitude) to allow the air to resume laminar flow before trying to pull out. Don Lopez, deputy director of the National Air and Space Museum and former Flying Tiger and test pilot, recalls seeing a pilot get into an accelerated stall in India, recover slightly, pull out too quick, and reenter the stall. "He did that three times before he hit the ground," says Lopez.

So just what is it that gave the Mustang the edge over the Curtiss P-40, Supermarine Spitfire, Lockheed P-38, and Republic P-47—all great fighters and all slower than the P-51? NACA airfoil series 4, for one thing. In 1938, engineers at the National Advisory Council on Aeronautics research center at Langley, Virginia, discovered that an airfoil that kept the flow of air laminar—smooth and attached—could reduce by half the drag produced by conventional airfoils. The first aircraft to make prac-

RICHARD VANDER MEULEN

The boys are back in town: Legendary Mustangs (right) and Mustangers came to Kissimmee, including Bob Hoover (below, standing, right) and Chuck Yeager (below, center, kneeling).

PAUL BOWEN

tical use of the discovery was the P-51, in 1940.

Edgar Schmued, Raymond Rice, Lee Atwood, and the rest of the talent trust at North American Aviation in the 1940s, for another. They turned out the AT-6 Texan advanced trainer, the Mustang, and the F-86 Sabre jet fighter as easy as one-two-three (see "Who Made the Mustang?," Aug./Sept. 1996).

A fascinating principle called the Meredith Effect, for a third. Under the influence of British scientist Frederick W. Meredith, the North American team designed the Mustang's cooling system to function as an air pump. With a variable exit, the system would heat the air streaming through it and eject it at the highest possible speed, thereby acting like a rudimentary ramjet.

At the heart of the Mustang's success is its Packard-produced Rolls-Royce Merlin engine, which replaced the altitude-challenged Allison V-1710 almost immediately, and the fact that NACA engineers and test pilots continued refining the aircraft's design. "It oughtta be good," says Steve Cavallo, a former NACA pilot who tested P-51s at Langley until 1947. "We spent the whole war refining the thing."

One of the P-51s Cavallo flew was a D model with an extended tail—now Frances Coutches' airplane—and he came to Kissimmee hoping to see it again. The weather, unfortunately, had kept the Coutches' Mustangs in California. But with so many P-51s there, it was hard to be disappointed. We watched one after another roll onto the runway and take off, parading before us like beauty pageant contestants. As they came back in to land, Cavallo pointed out that the pilots were "wheeling them in": touching down on the two main wheels, then letting the tail wheel drop, just as the cautious Lauderback had taught them to do. "You know the mark of a real pilot is to touch down on all three at once," Cavallo commented, remembering that, because the Mustang is such a skittish airplane on landing, he wheeled them in too.

Each aircraft was exquisitely restored. There was *Glamorous Glennis*, the P-51D that Chuck Yeager flew, and *Old Crow*, flown by his squadron mate Bud Anderson, both aircraft wearing the markings of the 357th fighter group. There was an array of "blue-nosers," P-51s of the 352nd fighter group, which in 1944 traded in its P-47s for the faster, longer-range Mustangs and began escorting B-17s all the way to Berlin. The most famous blue-noser is *Cripes A'Mighty 3rd*, flown by the 352nd's leading ace, George Preddy, and now owned by the wealthy Kermit Weeks, who has one of the most extensive private historic

RICHARD VANDER MEULEN

On the ground, P-51 fans bagged photos and autographs. Overhead, a North American F-86 Sabre shadowed its older brother (below).

aircraft collections in the world.

Of course, all these aircraft are role-playing. Very few of the aircraft at the gathering saw action in the war. The common practice among warbird owners is to acquire an example of an aircraft type and restore it as if it were one of the famous fighters of World War II or another conflict. Butch Schroeder, who also owns a P-47, found his aircraft in a garage in St. Louis and brought it home to Danville, Illinois, in six pick-up trucks and three trailers. After a 12-year rebuilding project, led by warbird restorer Mike VadeBonCoeur, the aircraft was reincarnated as *L'il Margaret*, a photo reconnaissance variant of the Mustang known as an F-6, and won grand champion at Oshkosh in 1994.

Yet like most of the beauty queens at Kissimmee Airport, the airplane's assumed identity has only a distant link to its real one. The airplane pretending to be *L'il Margaret* spent the war Stateside as a trainer, albeit in the same squadron as the real *L'il Margaret*.

Before *L'il Margaret* found its way into that St. Louis garage, it performed a low-level mission in Michael Coutches' back yard as a jungle gym for his children. (Frances Coutches insisted that the airplane not be taken from the back yard until her children were in school so that they wouldn't be upset. Brothers Robert and Steven had not seen the aircraft since that morning until they were reunited in Kissimmee and met Schroeder, the aircraft's new owner.)

One aircraft at the gathering that really is who it says it is—*Scat VII*—has worn a few disguises in its time. Its serial number identifies it as the last Mustang flown by World War II ace Robin Olds. Before Jim and Carol Shuttleworth bought it in 1992, it had been modified considerably by John Dilley of Fort Wayne Air Services. Dilley had put LearJet wings on the aircraft, cut down the canopy, and turned the airplane into a racer, *Vendetta*, which eventually crashed. Dilley managed to get the original wings back and sold the bundle to the Shuttleworths, who had the aircraft rebuilt into a TF-51.

But if the real airplanes couldn't make it to Kissimmee, some of the real pilots could. The Gathering of Mustangs and Legends was a field day for autograph hunters. Besides Yeager and Bob Hoover, the group of Legends included World War II aces Bud Anderson (who signed copies of his 1990 book *To Fly and Fight*), Ken Dahlberg, Robert Goebel, Richard "Pete" Peterson, and the illustrious Robin Olds; highest scoring Tuskegee airman Lee Archer; the Patillo twins—Bill and Buck, who had outstanding war careers and flew aerobatics in one of the Air Force's first precision demonstration teams and the Thunderbirds; and Apollo astronauts Bill Anders and Frank Borman, both Mustang owners. That evening, at a black-tie dinner hosted by Kermit Weeks at his Fantasy of Flight "attraction" ("We don't like the word 'museum,' " he warned), each of these pilots received a leather jacket, painted with the nose art of his airplane, and a round of applause. At the end of

ALEXIS VON CROY

PHILIP MAKANNA

The Mustang originally cost about $50,000, but today, owning one like Donald Duck *requires at least a seven-digit checkbook balance.*

the presentations, the group, at the instigation of Olds, sang a chorus of "Good Night, Irene," complete with two-part harmony—12 old airmen singing what they might have sung as 20-year-olds when their sweethearts wondered if they'd ever see them again. It was a touching moment. But fighter pilots will be fighter pilots. The next musical number Olds led can't be printed in a family magazine.

So how does a mere mortal go about getting a P-51? "Well, you have to have a lot of money," says Butch Schroeder. A fully restored TF-51 recently changed hands for $1.2 million. Then a good place to start is to get to know Paul Coggan, editor of *Warbirds Worldwide*, the bible among collectors, who not only knows everything about the airplane but also who owns what, who wants to buy, and who wants to sell. Coggan found the P-51 that eventually became Anders Saether's (also restored as *Old Crow*—"Mine was first," Saether says). It had been owned by someone who was caught "importing pharmaceuticals," says Coggan.

"There are a queue of people waiting to buy," says Coggan. "Three or four people at this event. We get letters every month looking for a P-51." The last bulk sale of the warbird was in 1984, when the Dominican Republic retired its fleet of nine. Brian O'Farrell of south Florida snapped those up, along with an enormous supply of parts. Coggan, who was there when O'Farrell took delivery, says that many of the parts were still packed in original North American Aviation crates.

Norm Lewis, also of Louisville and one of the first graduates of Stallion 51 training, was lucky enough to find one of the 200 P-51Ds built under license in Australia near the war's end, designated C17s and C18s. Production was more leisurely in Australia, says Lewis, and the workmanship is exceptional.

Every now and then a crashed P-51 turns up. Coggan thinks there are probably some in Russia and some in Indonesia. Mike VadeBonCoeur is working on one that was pulled from a lake in Uruguay. "It was pretty much Swiss cheese," he says. Practically the only thing that will be original in the restoration is the manufacturer's data plate. "That's enough," says Saether. "Then you have the airplane's soul."

If you have the money and find the airplane, there are four or five businesses in the United States rebuilding or restoring airframes and a like number overhauling Merlin engines. The majority of Mustang restorations today copy a modification ordered by the Army Air Forces near the end of World War II. So many pilots were killed in the P-51 during training that the Army finally decided to order a dual-control, dual-cockpit trainer. North American built 10 and a further 15 single-seaters were modified by Temco, an aircraft conversion operation in Dallas, Texas.

By Sunday afternoon, the Mustangs were gone. Some headed to Lakeland for the Sun 'n Fun fly-in; the rest went home to Indiana, California, Kentucky, New York. Tim Shea had never seen the airport look quite so empty.

The Terrible Two

They're just a couple of digits,

but they could wreak havoc.

How will the Y2K problem affect air travel?

by Billy Goodman

Illustrations by John MacNeill

What will you be doing New Year's Eve? Chances are you won't be flying, but that is just what the head of the Federal Aviation Administration plans to do. FAA Administrator Jane Garvey and her Year 2000 Office chief, Ray Long, will take a much-publicized commercial flight across the country that evening, and into the morning of the new millennium, to demonstrate that the nation's airways are safe and unaffected by Y2K computer problems. John Koskinen, chair of President Clinton's Council on Year 2000 Conversion, has announced that he too will fly on New Year's Eve and New Year's Day to show his confidence in the Year 2000 efforts of one of the most scrutinized federal agencies.

As the clock strikes 7 p.m. in the East—midnight, Greenwich Mean Time, which is how FAA computers reckon it—will they have anything to worry about? Almost certainly not.

Do you, if you plan to fly that evening or in the days and weeks that follow? Probably not. Experts are confident that airplanes won't start falling from the sky. The FAA insists that safety will not be compromised—that, in fact, it will be business as usual for air traffic on 1/1/00. "If [travelers] can get to the airport and get on an airplane, we'll take them wherever they want to go," says Brian Riehle, head of the Year 2000 office of FAA's Air Traffic Services division. "I think it will be a big non-event."

Riehle is alluding to what might be the most likely guise in which Y2K will rear its head and bite airline passengers: difficulties getting travelers onto planes in the first place. If there are power outages, for example, many people may be unable or unwilling to go to the airport. Many aviation experts expect some disruptions in air traffic at the date changeover, even as they discount the most extreme of alarmist predictions, such as the grounding of airplane fleets. Choosing his words carefully, Andy Kyte of the Gartner Group, an information technology research firm, says, "We believe there is highly likely to be significant disruption to air travel because of the lack of coordination among parties to insure that safety standards have been maintained." Nevertheless, Kyte and the Gartner Group have to be counted as optimists. Kyte says that aviation, because of its high degree of regulation and "the high participation of engineers in the industry," has strong information management and maintenance systems that ought to allow the major airlines to overcome inevitable glitches.

The U.S. aviation system may function at less than full efficiency for a time, agrees Chris Tebo, who is coordinating Y2K efforts for the American Association of Airport Executives. "Top airports will be operating," he says, but "maybe jetways won't function properly or the power supply won't function properly." Escalators may not work, he says, but "runways aren't Y2K-dependent," so airplanes will be able to land.

THE PROBLEM AND ITS ORIGIN

The Y2K problem is simply the latest and greatest of problems computers have with clocks and dates (in the past, many computer systems have failed to recognize a leap year). Y2K arose when programmers wrote programs that took the first two digits of the date as a given—that is, they hardwired in the "19," so it is hardly the computer's fault when it interprets "00" as "1900."

Many programs do not use the date, and those will be unaffected. Others


2000

merely put the date in the heading of a report, leading to an easily recognizable but superficial error without other consequence. But some software may use the date more integrally. For example, if the software measures time since service has been performed, and if it interprets 00 as 1900, then it may miscalculate the interval since the last maintenance and, depending on the programming, set off a warning or possibly even turn the hardware off. Or the software may do arithmetic with the date and perform an erroneous calculation, such as subtracting 99 from 00 and getting -99 (when the correct answer should be 1). It may even decide 1900 does not make sense and quit.

The two-digit convention has its origins in the 1950s and '60s, when users communicated with computers using punch cards, which contained instructions for the computer to follow (the program) and data for it to process. Computers had very little memory, and one line of a card had just 80 spaces for characters. Using two digits for dates—thus saving two spaces—made sense. When computer memory grew enough to make it unnecessary to abbreviate dates, the habit was hard to break. Contrary to current conventional wisdom, programmers in the 1970s and '80s often *did* know that the programs they were writing would not function properly when the year 2000 dawned. But they had little incentive to write programs that would work 20 or more years into the future because almost no one expected software to last that long. Instead, wrote National Air and Space Museum curator Paul Ceruzzi in the *Washington Post*, "From the beginning of programming, electronic digital computer people recognized that once they'd written a piece of code that worked and was free of "bugs" or errors, that code was precious and ought to be reused...." As Ceruzzi points out, parts of the original MS-DOS operating system survive in modern versions of Windows, the most popular operating system in the world.

Among the vanishingly small number of programmers who foresaw a year 2000 problem and tried to do something about it is Bill Schoen, a mainframe systems analyst and Y2K expert with Remtech, a Michigan consulting firm, who hastens to correct anyone who blames programmers for the mess we are in. Twenty-five years ago, recalls the 50-ish iconoclast, he was coding his first big job when "I went to my boss and told him: 'One thing that bothers me about this—it's not going to work in the year 2000.' He just rolled his eyes and said, 'By then I'll be retired.' " Schoen tried in vain to warn those responsible for the systems he was programming that they would not work in 2000 unless they were specifically programmed to work then, but he was met with attitudes ranging from unworried to downright hostile. Taking the year 2000 into account, systems specialists knew, would create a lot of extra work. After all, programmers couldn't unilaterally start using four digits for dates, since many programs access databases with two-digit dates or interact with other programs using two-digit dates.

Schoen issued what is probably the first public warning of the year 2000 problem—in 1984—in an article about him in *Computerworld*, then and now a widely read computer industry magazine. Schoen recalls—bitterly—the reaction to the article: "I thought, *Now you've done it, you've blown year 2000 wide open.* But what happened was nothing. No follow-up on the article, no academic articles, no one writing on system development addressed the issue. The biggest thing in data processing, and everyone missed it."

Fifteen years later, the FAA has found lots of old software that survived, much of it part of the National Airspace System (NAS), the computerized network that operates the U.S. air traffic control system and is currently responsible for far more air traffic than anyone anticipated. The software has been continually upgraded and rehosted (moved to a new computing platform), but some of it is essentially the same code that was written 20 or 30 years ago. Now that code must be assessed and fixed. With staff programmers to do much of the upgrading and rehosting, the FAA may be in better shape than many large organizations.

The millennium bug is simple enough to explain and even to fix. Why then, with governments and businesses spending billions of dollars on the problem, are some people still predicting global chaos, financial meltdown, or worse?

The problem is scale. Large organizations have hundreds of computer systems and programs. The FAA has 645 systems scattered among its seven lines of business. About 430 are considered "mission-critical"—their operation has a direct impact on flying safety in the

RUMOR: At the rollover, Lufthansa plans to stop flying for a few days.

FACT: False, says company spokesman Bill Yanson. "Lufthansa has no plans to not fly on or around January 1, 2000," he says.

NAS. Furthermore, NAS software runs to some 23 million lines of code, and in many different computer languages.

In addition to mainframes and desktop computers, there are something like 10 billion to 40 billion microprocessors worldwide—tiny computers with "hard-wired" software that have been built into everything from automobiles, microwave ovens, and automatic teller machines to commercial jets, baggage conveyors, and runway light controls. These embedded systems are often not apparent to the user and not easily changed. Embedded systems also control many industrial processes at chemical plants, power stations, and telephone switching operations. The vast majority of these have no date sensitivity. But some—it may be one percent, it may be 10 percent, no one is sure—are date-sensitive and must be corrected or replaced.

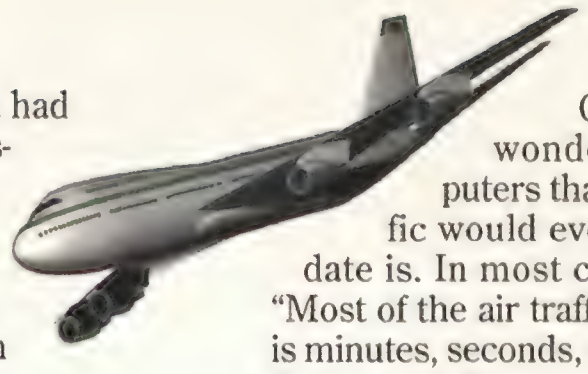
Finding affected lines of code or date-sensitive microprocessors is the difficult task, say several programmers and embedded-system engineers. In both cases, lack of documentation is a problem. Take a modern computerized baggage handling system, for example. An airport may have bought the system from a manufacturer who subcontracted production of the system's brains to another company. The subcontractor, in turn, may have bought computer chips from several different vendors, some now out of business. Airport Y2K program managers are sometimes finding it difficult to get specific Y2K compliance information from vendors because of this kind of documentation breakdown along the supply chain. In any event, several of these managers say that they are not relying on certification by others but are testing systems themselves.

AIR TRAFFIC CONTROL

In mid-1998 government watchdogs like the General Accounting Office had little confidence that the FAA could make all its 430 mission-critical computer systems ready for year 2000. Criticism from GAO, Congressional committees, and others appears to have been motivating. At the end of 1998, the FAA reported that it had fixed all date-sensitive systems and begun the time-consuming step of testing the fixes. Many systems have been tested individually at the William J. Hughes Technical Center in Atlantic City, New Jersey, which has copies of most of the FAA's mainframe computers and has the capability to mock up just about any of the air traffic control centers. But that's a laboratory; what about out in the actual system?

Much more ambitious real-world testing was conducted last April at Denver's Air Route Traffic Control Center. This "en route" center is one of 20 nationwide where controllers monitor and direct high-altitude traffic that is neither departing nor arriving but on its way somewhere—hence the name. The FAA linked several computer systems at Denver and elsewhere to test how they pass data back and forth and how they will deal with the rollover to January 1, 2000. Each en route center has a primary operational computer and an identical one for backup; at Denver they can be split so that as some controllers handle live traffic, others shadow them on the backup, testing the fixes. The test went beyond checking the ability of a few ATC computers to pass information correctly back and forth; it involved telecommunications linkups between adjacent en route centers, with telephone giant MCI participating, and involved other data interfaces, including those with airlines and the National Weather Service.

Not everyone is confident that the entire NAS can be tested adequately. David Hall, a risk manager and consulting engineer with considerable avionics experience, concedes that the FAA has formidable testing expertise and capability, but he wonders, "How can they test every aspect of the air traffic control system throughout the date range of interest?... I don't think you can shut down the air traffic control system" to find out. He agrees that the multi-system tests conducted in Denver were necessary, but he thinks they weren't enough.



Of course, one might wonder why the computers that monitor air traffic would even care what the date is. In most cases, they don't. "Most of the air traffic control system is minutes, seconds, or days," says Bill Peters, a staff engineer at the Technical Center. "We do very little with years or months. Radar data, once more than 12 seconds old, is of no value."

Riehle, the ATS Year 2000 chief, distinguishes three parts of the National Airspace System: applications, maintenance, and support. Applications software processes radar and flight data and feeds it to air traffic controllers. Maintenance software keeps track of the hardware, scheduling maintenance and parts replacement. Support software helps programmers and engineers write and update software and package it for the field. More than "95 percent of the things that have to be fixed are in maintenance or support," Riehle says, "not in the part that processes flight plans or puts data on controllers' screens."

One system that has received a disproportionate amount of attention is referred to simply as the Host, for its central role in storing and disseminating air traffic control software and data. Forty of these IBM 3083 mainframes are found at 20 en route centers in the continental United States: at each center, one assists controllers handling high-altitude traffic and the other serves as a backup. The computers are of an early-1980s vintage; they are no longer produced, and the supply of spare parts is dwindling. IBM advised the FAA to replace the Host, saying it couldn't guarantee it would be Y2K-ready. Early this year, the FAA began replacing the 3083s with IBM 9672s, which will be Y2K-compliant. There will be an interim period during which the new computer will "emulate" the earlier model's operating system so that the existing software will operate on it. Once new software is ready, the computer will shift to a faster operating system.

With a poor track record of implementing new technology, the FAA worked to make sure the 3083 would continue to function if necessary in 2000; Administrator Garvey announced in late summer 1998 that 3083s were ready for the millennium, but by spring 1999,

more than half of them had been replaced by 9672s. The main problem facing those renovating the Host was that it runs software written for an earlier machine in the 1960s and '70s, using languages no longer in common use. Different teams of programmers were called upon to assess and fix the applications software and the microcode—software that is analogous to a personal computer's operating system.

Two former IBM programmers—both of them among the best at working with 3083 software—were brought to Atlantic City to troubleshoot the microcode. Luther Woodrum, who began writing programs in 1957 at the age of 18, says he was greeted by tens of thousands of pages of microfiche on which 50 million lines of microcode were written. "The first thing I told them," he recalls, "is that this isn't going to work." Woodrum asked for and eventually got a listing he could read on a screen, found the five million lines that make up the current microcode, and then wrote a program to find references to the date. Ultimately, he discovered a few instances where the code did not account for 2000 being a leap year—it would call the 60th day of the year March 1 instead of February 29. But the error leads to nothing more serious than faulty displays, so corrections were not really necessary, he says.

The tech center's Peters agrees. "Our concern," he says, "is that any time you make changes in the microcode, you open the system to risk [because fixing bugs sometimes introduces other bugs]. We're taking a conservative approach." A cautious approach seemed fitting for the conservatively dressed Peters, who is widely regarded as an engineer's engineer, as he discussed the Technical Center's work during a visit last September. He and his colleagues have been developing most of the initial Y2K programming fixes for air traffic control computers.

Behind locked doors in the middle of the modern Technical Center is the Central Computer Laboratory, two floors full of humming mainframe computers. The center has three 3083s, blue and white water-cooled machines roughly the size of minivans.

FAA programmers and engineers use these machines to perform initial tests of Y2K and other bug fixes. While consultants assessed and fixed the microcode, Peters and some of the programmers who work with him checked the applications software, which turned out to fail Y2K readiness in a fundamental way: On startup in 2000, the computer would understand 00 as 1900.

If undetected, the Host would have failed to match the date with the proper day of the week. About the only task in which this would have mattered is in something called "bulk flight processing," the practice of grouping all scheduled airline flights by day of the week: All Monday flights are grouped together, all Tuesday flights, and so on. This is a convenience for controllers, who can avoid the tedium of entering airline flight plans because each day's flights are already loaded. January 1, 1900, was a Sunday, however, and January 1, 2000, will be a Saturday. Uncorrected, the Y2K bug would lead to the wrong day's flights being presented to the controllers.

At the Technical Center last September, a programmer (whom the FAA asked me not to identify) in a cubicle smaller than a 3083 described the problem and the simple four-line correction, or "patch," which employed the most common Y2K repair technique, "windowing." While it still uses two-digit years, the computer is instructed to use 19 before a certain range of two-digit combinations and 20 for the remainder. For the Host, 00 to 49 mean 2000 to 2049; 50 to 99 mean 1950 to 1999. That means, of course, that this particular Y2K problem will be delayed 50 years, becoming a Y2050 problem. But not even the FAA's harshest critics believe the current software will still be running then.

If, despite all the efforts to prevent it, one or more air traffic control computer systems or radars fails, controllers will have to fall back on the manual methods they use now during computer malfunctions. They will keep track of aircraft by updating paper "flight progress strips" based on conversations with the aircraft. When that happens, an "en route" airplane must follow 20 miles or 10 minutes behind the aircraft

RUMOR: If all airplanes are grounded, there will not be enough room for them to park in the world's airports.

FACT: While this sounds like an urban legend, it in fact has more than a grain of truth. If all planes were brought down at the same time, says Denis Chagnon, spokesman for the International Civil Aviation Organization in Montreal, there wouldn't be space to park them all at gates or easily accessible areas. Taxiways, hangars, and the area around hangars would have to be used.

ahead instead of the normal five miles; the result will be delays.

If the air traffic control computers work properly, will there be airplanes in the air to take advantage of them? That depends on the answers to at least three questions: Will the airplanes themselves be ready? Will airports be in shape to permit takeoffs and landings—and to accept passengers? And will insurers provide coverage to airlines and others in aviation so that they will be protected in the event of mishaps?

AIRPLANES

Airplanes are made by some of the largest, most technically advanced industrial firms in the world. These companies have lots of information technology and engineering expertise. They have a high degree of motivation not to fail. And, at least in the case of Boeing, they have had a long head start to fix the problem.

Boeing, according to spokesman Bob Jorgenson, began to take the year 2000 problem seriously and institute corrections in 1993 because the company orders some materials seven years ahead of when they will actually be used (it takes a long time to plan the manufacture of a modern airplane). When analysts began projecting such materials needs for 2000, their computers did not recognize the date. By early 1994, Jorgenson says, Boeing had Year 2000 teams and a plan in place. Customers and suppliers, in turn, were warned that the date change was something they ought to pay attention to.

Airbus Industrie, Boeing's main competitor in the commercial jetliner field, also began to address Y2K issues several years ago.

Modern jetliners have thousands of microprocessors doing everything from assessing the fuel supply to helping to navigate the aircraft. Very few, according to Boeing and Airbus executives, are date-sensitive. Boeing spokeswoman Mary Jean Olson says that only three systems found in some Boeing aircraft are date-sensitive, and none compromise safety. She says that some versions of the flight management system, which crews use to verify navigational databases, may give "nuisance displays." While not dangerous, such annoyances conflict with Boeing's "quiet, dark" cockpit philosophy, which says: Alert pilots only when something about the airplane or the flight is abnormal. The worry is that the displays may distract the crew or hinder normal pre-flight procedures, thus delaying takeoff. For example, a display might read 111 or 100 instead of /00. In some cases, the display would include the message NAV DATA OUT OF DATE, even when the navigation database is current.

One of the affected systems is produced by Honeywell. "This will have no impact, other than it might cause a pilot to question the display," says Paul Zorovich, the Y2K program manager for Honeywell Commercial Aviation, which makes avionics, including some versions of flight management systems. Boeing has notified airlines of the problems, advising them to upgrade software or hardware.

In the course of producing its airplanes, Boeing uses some 180 computer systems for, among other things, identification of parts, scheduling, inventory management, planning, and shop floor control. By spring, all had been assessed, fixed if necessary, and tested individually, says Jorgenson. Boeing was in the process of testing systems together to make sure, as he put it, that "everything is fine when they talk together." Indeed, he says, there have been "no problems at all."

RUMOR: At the date changeover, elevators will plummet or freeze.

FACT: Elevators may be the only place more feared than airplanes as a place to be at midnight on December 31. Most won't be affected by the date changeover, says Sam Mehta of Otis Elevator. If one were to fail, say because its microchips thought it hadn't been inspected in 99 years, it would likely return to the main floor and open its doors and then stop. But elevators are being checked at airports.

AIRPORTS

Airports are used to dealing with bad weather and the resulting flight delays and cancellations. Good thing too, since heavy weather is just the way some Y2K experts describe the expected impact of the date change at U.S. airports. Tom Browne, head of the Year 2000 program of the Air Transport Association, the trade group representing major U.S. passenger airlines and cargo carriers, says the rollover "won't be any different than having a major snowstorm." He and his team have developed a list of about 120 systems in airports that must be checked, including: runway lights, baggage systems, parking lot

systems, elevators, jetways, and fire fighting equipment. A year ago Browne found many manufacturers slow to respond to queries.

That is changing, prompted in part by the president signing a law limiting liability of companies that share Y2K information in good faith. The ATA effort—designed to centralize data collection and eliminate some duplication of effort—was beginning to get some answers, and Browne was encouraged. At least some runway light systems checked out okay, as did some passenger boarding bridges. "Some airports might be without power," he says. "Some might be without telecommunications. At some, specific equipment might fail. On any given day at airports, people are working on contingency plans and capacity [of the system] is reduced. The only difference here is scale."

Most, if not all, major airports and many lesser ones have Year 2000 offices and people in charge of assessing, fixing, and testing their systems. At Seattle-Tacoma International Airport, one of the nation's busiest, Burr Stewart leads a 32-person team that by the fall of 1998 had assessed 114 systems. They found 14 percent were not sensitive to the date in any way they could determine, 23 percent were certified as ready by vendors, 34 percent were certified by vendors to be non-compliant, and 29 percent were unknown.

What was non-compliant? Baggage conveyors, for one. A belt run by Alaska Airlines and controlled by a desktop computer might have failed without a software upgrade, stopping altogether or sending bags to the wrong destination. Other belts required updated microprocessors; without them, a Sea-Tac spokeswoman says, the belts might have stopped, requiring manual baggage handling. Moreover, conveyor belts and other equipment are linked to computers that track maintenance; a Y2K failure in one of them could lead to erroneous records.

This kind of recordkeeping software and microprocessor failure is a recurring theme. An individual failure would be annoying; numerous failures at one airport could disrupt operations.

Al Graser, the general manager of LaGuardia Airport in New York City, relates one example of a Y2K failure that would be annoying or worse if it were not caught and corrected. There, the system that controls access to the ramp requires that employees swipe an ID card through a reader and enter a personal ID number. The system is not Y2K-ready: Cards with expiration dates in 2000 would not allow the holder to enter the airfield. LaGuardia is updating its system, says Graser; meanwhile, all cards expire in December 1999.

Not everyone is confident that the date change at airports will be smooth. Hall, the Y2K consultant who is an expert on embedded systems, believes that ubiquitous microprocessors will cause airports, and others, more problems than they expect. "No one understands the full pervasiveness of embedded chips in their enterprise," he says, adding that in his experience, the scope of the task is never apparent until a full inventory of chips is made. "No [single] department has control or inventory of all this stuff. Upgrades have come along and nobody has kept track."

INSURANCE

Airplanes will not fall from the sky. Air traffic control computers will probably not lose track of flights. Despite some glitches, most airports may even function relatively smoothly. That leaves one potential show-stopper: Will airlines and others be able to purchase insurance to cover Y2K risks? Without seamless insurance coverage, an airline may be unable to fly.

Andy Kyte of the Gartner Group says, for example, that he would be happy to fly on New Year's Day 2000 "on a 'First-World' airline," but is not sure he'll be able to. "Not because of any technical failure," he notes, but because he is not sure insurance companies will come to the same assessment as the Gartner Group. "It's one thing for us to come to an honest assessment of risk, another for insurance companies to commit hundreds of millions of dollars to it.

"It is not that there is significant risk but that nobody knows how to measure the risk," he continues. "If you can't measure the risk, then how do you set the premium?"

However, with many insurance and reinsurance policies renewing in January, a position has emerged that apparently satisfies airlines and others and should permit Kyte to fly. Insurers, says Harold Clark, chairman and CEO of United States Aviation Underwriters, are writing exclusions for Y2K into their policies, then adding back coverage for bodily injury and property damage.

"As it stands right now, airlines will have insurance covering them against [Y2K-related] accidents or occurrences—such as turbulence or food poisoning—that give rise to bodily injury or damage to property," says Clark, whose company manages a pool of insurance companies. "We've tried to clarify what we won't cover, what we call business risk. For example, a security lock on a gate has a Y2K failure and somebody can't come in to start the plane. We don't intend to cover those risks."

Insurers have concluded, he says, that "airlines, manufacturers, and governments have run scenarios and there ought not be something dire tied to computer failure."

OTHER COUNTRIES

Civil aviation systems will be ready for Year 2000 in the United States, Canada, Great Britain, and other developed countries. There will be glitches for sure, but in the view of most experts, air traffic computers are likely to be Y2K-compliant.

In the rest of the world? That's another story. Joe Morgan, who handles international issues for the FAA Y2K Program Office, admits that he has concerns about less developed countries. "We really don't know what they are doing," he says. "We don't have good intelligence that they have effective Y2K programs or any Y2K program—al-

though we are working with ICAO [the International Civil Aviation Organization] to get that information."

In May, 1998, ICAO surveyed 185 member states. By November 30, ICAO had received 104 responses. Not one country reported that it was Y2K-ready. While 36 countries reported being close, with Y2K programs in place and contingency plans in development, 39 either had no program or could not convince ICAO that their air traffic systems would be ready.

ICAO member states specified July 1 as the deadline for reporting on their Y2K programs and compliance, says spokesman Denis Chagnon. Until then, he says, ICAO is working to identify countries with problems and help them develop and implement an action plan. "If a state does not comply [with reporting] or is identified as not being Y2K-compliant, airlines may not fly to that country—and you can imagine the economic fallout of that," he says.

Indeed, international aviation authorities and some airlines have begun to talk quietly about no-fly zones—countries or regions that do not have air traffic systems ready for the year 2000. Dutch airline KLM was one of the first to announce that it might not fly to some countries. Spokesman Hugo Baas says, "We cannot promise to fly by 2000, but we promise we will look very critically around the world, and where we have doubts will temporarily ground aircraft."

In Britain, some members of parliament urged the Civil Aviation Authority to develop a blacklist of airlines to be excluded from British airspace and to inform Britons by September of airlines that pose risks. Tony Wharton, Y2K program manager for the CAA's National Air Traffic Services, would not directly address whether no-fly zones were being considered but said, "Like everyone else, we're engaged in contingency planning."

In assessing the CAA's own systems, Wharton noted, "quite a few anomalies" were discovered; as in the United States, most problems would not have affected air traffic operations, he says, but were associated with the collection of engineering information and analysis.

In the United States, the FAA is paying special attention to the Y2K readiness of six countries that account for 60 percent of Americans flying abroad: Mexico, Japan, Britain, Canada, the Bahamas, and the Dominican Republic. Most are doing well, says Morgan, who has met with their Y2K teams.

During the past year, Y2K has gone from being an issue only a few geeks paid attention to, to the potential End Of The World As We Know It, to a manageable problem that may hit North American airports like a winter storm. Some doom-and-gloomers—including those with money to make—continue to forecast chaos, while Pollyannas see reasons for optimism. Ask thoughtful experts "What will happen when the clock rolls over from 1999 to 2000?" and they often give an arresting response: "We don't know." Despite the testing, one says, "No one knows exactly what will happen. No one can replicate all the conditions that will exist in Year 2000 in order to validate that [computer systems] will work."

So go ahead and make New Year reservations (the computer reservation systems are working without problems). But be patient. Wear comfortable shoes. Take along something to read. It could be a while.

RUMOR: Reuters reported in late December that when the British airport operator BAA Plc tested a baggage handling system by setting the clock forward to 2000, the system "failed to recognize the bags and sent all the bags down the 'mis-sort' chute."

FACT: The story implied that the test had just happened. In fact, a BAA spokesperson says, the test was conducted two years ago, to see how systems were affected. The baggage-handling system has since been fixed.

ROBERT REEDER

Glenn Martin developed mass production techniques to build Marauders and Mariners—and a town for his employees.

by John R. Breihan

In 1939, American aircraft factories began to expand to meet the Axis challenge. Like powerful magnets, they attracted adventurous young workers from across the country. But building airplanes requires a lot of space, for both factories and runways. Plants usually were out in the sticks. Where would all these aircraft workers live?

Glenn L. Martin was one of the first manufacturers to face this question. Ten years earlier, foreseeing the future in all-metal aircraft, he had built a factory in the rural hamlet of Middle River, Maryland, 10 miles outside Baltimore. Martin conducted what he called "a profound study of aircraft industry sociology," which convinced him that the glamour of the industry would attract workers from the city—despite the fact that aircraft industry wages were lower than those of other, more accessible manufacturing plants. Martin could take advantage of cheap land beyond the Baltimore streetcar lines. All that would be needed was a good road from the city

COURTESY GLENN L. MARTIN AVIATION MUSEUM

The B-26 Marauder forged a true company town, visible in the aerial shot at right, to house the burgeoning population that came to work at the Martin plant outside Baltimore, Maryland.

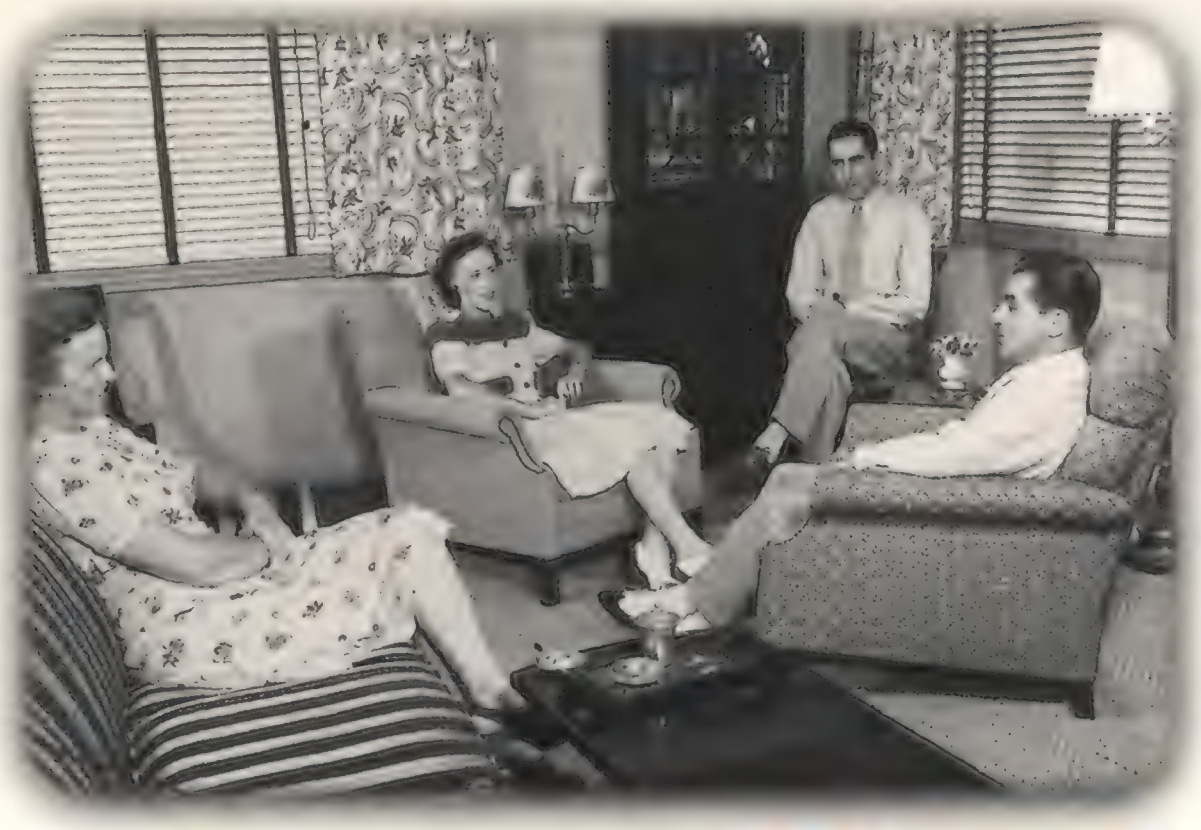
COURTESY GLENN L. MARTIN AVIATION MUSEUM (3)

instead of the two-lane country roads then winding through eastern Maryland.

Despite several efforts, Martin did not get that road built during the 1930s. But by 1939, he succeeded in landing a series of large contracts—first from the French for streamlined Model 167 bombers (later called Marylands by the British), then from the Army Air Corps for B-26 Marauders and from the Navy for PBM Mariner flying boats. The Martin plant tripled in size, and a second plant was built at Middle River just for the B-26. The workforce rose from 3,600 at the beginning of 1939 to more than 30,000 three years later. Traffic jams on the way from city to plant became legendary. Even *Life* magazine took notice. A December 1941 story described "twelve tormented miles" through which workers "snail and snarl, shrouded in gasoline fumes" at the beginning and end of each of the Martin plant's three daily shifts.

After Pearl Harbor the situation grew worse. Eventually Martin's Baltimore plants employed more than 54,000 workers. Given the traffic nightmare, migrant workers desperately sought housing near the plant. But with a pre-war population of 161, Middle River had little to offer. This was not for lack of trying, as private residences became boarding houses and back yards became trailer parks. Ed Blazek, who traveled from South Dakota to take a 47.5-cent-an-hour job on the night shift, drove around for hours with a Martin personnel official before finding room and board with a farmer. After arriving from the Pennsylvania coalfields, Lester Hopkins lodged with 30 others at the home of an enterprising Mrs. Tomlinson. In addition to housing lodgers in her home, she crammed more in a trailer and even converted a chicken coop in her yard into a dormitory for women workers. "I was the only one that didn't have to roll out of bed and let somebody roll in my bed," Hopkins recalls. "Everyone else there, she was giving them three shifts. You got to sleep eight

Workers from far and wide arrived in Middle River to find a housing shortage. Trailers (below), boarding houses, even chicken coops sufficed until Martin created suburbs of Cemesto houses (above).



hours and then you got up"—to give your bed to the next man.

Poor housing and transportation were reflected in turnover rates that caused growing alarm. Martin's answer: a new community of low-cost homes built on farmland around the plant.

Back in 1939 the company had tried building conventional garden apartments near the plant, but rents proved far too expensive for workers like Ed Blazek. Characteristically, the Martin Company then applied to house building the same principles it was using to build airplanes: new lightweight materials and structures and simplified assembly for mass production. After a systematic study of new building materials, Martin chose Cemesto, insulation board covered on each side with asbestos cement and hot-pressed into four- by 12-foot panels. Just under two inches thick and weighing 235 pounds, a single panel of Cemesto could serve as both exterior and interior walls, providing both strength and insulation. Unskilled laborers could quickly nail the panels to lightweight timber frames and prefabricated doors and windows. The new homes cost about a thousand dollars less than comparably sized conventional houses, which went for around $4,000; rents could be as low as $30 per month.

Martin contracted for 600 Cemesto houses to be built in two new neighborhoods. Construction began during the spring of 1941, and residents were moving in by August. The homes were small—28 by 24 feet—but efficient. The fledgling architectural firm of Skidmore Owings & Merrill (later to design the U.S. Air Force Academy and many corporate skyscrapers), hired to design the houses, managed to squeeze in two bedrooms, bath, kitchen, dining alcove, and 13- by 18-foot living room with two picture windows, all on a 48- by 100-foot lot. Kitchens featured built-in cabinets, a two-bowl sink, electric refrigerator and water heater, and a hotplate and countertop oven, and their construction rate was an efficient six per day.

Houses in Aero Acres, with its heritage incorporated into street names, featured two broad picture windows (above). Harry Hodgin, first president of the Aero Acres Civic Improvement Association and owner of three Aero Acres homes, remains a neighborhood booster.

The two neighborhoods, Stansbury Estates and Aero Acres, were laid out in accordance with the latest suburban planning theories. On a wooded peninsula adjoining the factory, the designers grouped the houses in "superblocks." Houses faced away from the street into mid-block greensward. On a flat former strawberry field a mile inland from Stansbury Estates, the designers used what turned out to be the more common suburban plan: gently curving streets (designed to keep down traffic speeds), and pedestrian paths leading to a central playground, all separated from high-speed traffic on the dual highway finally being built to connect the factory to Baltimore. New schools and water and sewer lines were courtesy of the federal government. Aero Acres streets were named after aircraft components: Fuselage Avenue, Elevator Road, Yawmeter Drive, Compass Road; Gyro, Longeron, Propeller, Stabilizer, Left Wing, and Right Wing Drives. Also separate from the houses was a strip shopping center, one of the first in Maryland, with a covered walkway of shopfronts facing a large parking lot.

So popular was this pattern that it was soon duplicated in additional worker housing provided at Middle River by the federal government. Because of the rural site, the Farm Security Administration, well known

ROBERT REEDER (2)

COURTESY GLENN L. MARTIN AVIATION MUSEUM (3)

Community spirit abounded among Martin workers, not only at home but at war bond rallies (top), on the production line of A-30 Baltimore bombers (above), and on the countless sports teams the company sponsored.

for its migrant labor camps out west, was brought in as a developer. On a parcel adjoining Aero Acres, the FSA contracted with Martin to build another 400 Cemesto houses on the same street pattern. After this, Cemesto production was monopolized by the only wartime project with higher priorities than the aircraft industry. The Manhattan Project turned to both Skidmore Owings & Merrill and the Cemesto company to build their secret town, Oak Ridge, Tennessee.

Across the new highway from Aero Acres, the FSA erected another 600 houses for Martin workers using more conventional plywood-panel prefabrication. Designed by Hale Walker, planner of the famous new Depression-era town of Greenbelt, Maryland, Victory Villa also featured curving streets, pedestrian walkways, and 30 examples of that other soon-to-be standard of the suburbs, the cul-de-sac, along with another strip shopping center. After 1942, private developers joined Martin and the FSA, building both prefabricated houses and garden apartments for aircraft workers. The population of the area around the aircraft factory grew to more than 20,000.

The new residents called it a Garden of Eden. The houses were far superior to the crowded apartments, trailers, and "hot sheet" boarding houses like Mrs. Tomlinson's, and it was exciting to be a pioneer in a brand-new, classless community. Harry Hodgin, an original resident of Left Aileron Drive, recalls: "We all had a common purpose. We were newcomers. We came from North Carolina, Texas, Florida and Tennessee, West

Virginia, and New York. We had engineers here, and we had technicians, and we had people who worked here as truck drivers. We had teachers, managers, and supervisors—a real mix of the culture."

The *Baltimore Sun* observed that "this infant community is not embarrassed by an economic caste system. There are no rich, no poverty-stricken. Virtually all are employees of the Glenn Martin Company, with little variation in wage scales, hence the economic level is flat as the top of a table. There are no palaces, no hovels. Houses are as like as peas in a pod."

That could be disorienting. Marie Buchanan, a former country girl from West Virginia, came home with a friend one night to find that "the houses looked so much alike we went into the one next door—we just miscounted. My sister had said she'd leave the door open for us, and this door was wide open too. The people were in bed sleeping. They said, 'Somebody's in here!' We slipped out so quiet!"

Still, loneliness could be a problem for the transplanted workers and their families. Baltimore did not always take kindly to newcomers, and in any case the city and its resources were 10 miles away. The newcomers had to look to themselves and to the efforts of government and company. Aero Acres had a USO set up for both servicemen and displaced war workers. "They had something going on all the time," Edna May Kneavel recalls. "They gave movies on Fridays. We had square dancing on Friday. They gave educational classes.... I learned shorthand. The classes went on all day long and into the night. No matter what shift you worked at Martin, you could do something." James Cody, a federal employee who managed Victory Villa, provided a similar range of activities at the Community Building, where scout troops, church congregations, civic clubs, bridge leagues, and a chess club were organized. The Martin Company, which had provided worker-friendly recreational activities back in Cleveland in the 1920s, concentrated on sports, sponsoring bowling teams, archery, skeet, golf, volleyball, basketball, and (Glenn Martin's favorite) baseball. The company president was always on the lookout for good players for the Martin Bombers and Bomberettes, terrors of the industrial leagues. Their small stadium outside the plant—the bleachers shaded by a B-26 wing section—was often filled with locals.

The Martin Company held annual "family days," with displays of aircraft and machines and of course a flyover by the latest factory projects. The first family day, in September 1942, drew an estimated 130,000 "Martineers," "Martinettes," and their families and friends to the factory airfield. On the speakers' platform actor-director Orson Welles, opera soprano Rosa Ponselle, and Lucy Monroe, RCA-Victor's "Star Spangled Banner Girl," stood next to Glenn Martin. In the background both plants continued work without interruption.

The plants were considered a prime enemy target. They and the whole neighborhood were elaborately camouflaged and defended by anti-aircraft guns. Nighttime blackouts and air raid drills could

Early residents like Jim Coffman and Harry Horney (bottom) recall that life in Middle River revolved around the B-26, here trundling from plant to airfield (above).

ROBERT REEDER (2)

Victory Villa kept the aviation-related street names but used conventional construction (above). Dean and Ivy Akers started out in a trailer, then graduated to a house on Compass Road. Today they live on Walkway Court (below).

be scary, although Marge Barhight remembers her parents and neighbors making a party out of huddling for shelter in a community building (although rumor had it that Cemesto houses were particularly resistant to bomb damage). And there was the noise. By 1944 Martin was turning out more than 200 B-26s a month. All had to have their engines tested, then taken for at least one test flight. Carol Dick, daughter of James Cody, who lived across the street from the Martin field, recalls: "They would line the B-26 bombers up one after another—it must have been a half a mile—and they would rev those motors up. They made a tremendous amount of noise, and of course there was no air conditioning. In the hot summer, all your windows were open. You almost felt as if you were sitting next to the plane."

ROBERT REEDER (2)

Major streets separated each of Martin's two factories from the field. Gates and "Airplane Crossing" signs marked where the B-26s, Marylands, and A-30 Baltimores were wheeled across the roads for testing. The Navy's PBM seaplanes left under their own power, taxiing down Middle River, where their wash often upset canoers like Carol Dick.

But this was a community rooted in aviation, and the local favorite was the B-26. Nearly 3,700 were built in Middle River. "In this area, the B-26 was something special," recalls Ray Barhight. "Your family talked about the B-26 like it was part of the family. It was commonplace to have a model of the B-26 sitting on your coffee table. It might have been an ashtray. You'd have something with a B-26 on it."

Most of the new housing developments near the plant carried on the Aero Acres naming system. Victory Villa included Propeller Drive, Chandelle Road,

Tachometer Court, and Run Way and Taxi Way. Streets at the adjoining apartments—Selfridge, MacDill, Hickam Roads—commemorated Army Air Forces bases. Mars Estates nearby, named for the giant Martin flying boat, had streets named after aerial heroes: Doolittle Drive, Rickenbacker Road, and Seversky Court. And of course Orville and Wilbur Roads both intersected Kitty Hawk Drive.

Counterparts of Aero Acres arose outside other aircraft plants across the country, prototypes for both the prefabricated building methods (though not the Cemesto) and the street layouts that would be used in more famous mass suburbs built after the war: the three Levittowns, Chicago's Park Forest, Los Angeles' Lakewood, and others that enabled Americans to take to the suburbs.

Today, life goes on along Hydroplane Drive, Nacelle Road, and Torque Way. The original houses are still there, now mostly owner-occupied since the company and government sold them off after the war. The original Cemesto walls have in most cases been encased in aluminum or vinyl siding. Once identical, the houses have blossomed into a variety of designs to fit the needs and tastes of two generations of residents. Harry Hodgin still owns the house on Left Aileron Drive he picked out in October 1941. Lester Hopkins, who married a girl from Mrs. Tomlinson's chicken coop dormitory, still lives nearby, as does Jim Coffman, who runs Coffman's Snack Bar, a popular Aero Acres diner.

Just after the war some of the residents tried to change the street names. Gerri Gray recalls that department store clerks would just laugh at her when she asked for a package to be delivered to Blister Street. But it fell through, and all the names are still in use.

The Martin Bombers' ballfield is now a vacant lot, but sports teams still operate out of the Victory Villa Community Building and a new Salvation Army Boys and Girls Club on the site of the Aero Acres USO. The old B-26 plant is now a government warehouse, but the other Martin plant is still in the aviation business as Middle River Aircraft Systems, now owned by General Electric Capital and building thrust reversers for airline engines. Martin Airport still accommodates Maryland Air National Guard and general aviation craft. And every September for the past 10 years, thousands of people have gathered there for an airshow that brings the roar of big Wright and Pratt & Whitney engines back to Aero Acres.

Even the post office was initially consigned to a trailer (above). But by the mid-1940s, when Glenn Martin dedicated a statue at Victory Villa (below), his suburbs had become a widely imitated model.

COURTESY GLENN L. MARTIN AVIATION MUSEUM (3)

"European Air War's outstanding gameplay and wealth of features make it the current leader of the WWII simulation crop" *-PC Gamer, 89%, Editor's Choice Award*

"This World War II simulation captured the feeling of being in a living, unpredictable combat environment better than any other sim released this past year" *-Computer Gaming World, 4 stars*

"European Air War succeeds at providing the experience that makes arm-chair fighter pilots believe they're truly leaving their mundane surroundings behind" *-Gamespot*

RACKING UP

"No previous sim covers so many different weapons and so many tasks in detail... it's all here and it's all beautifully executed" *-PC Gamer, 95%, Editor's Choice Award*

"Falcon 4.0 is the deepest, most complex air combat sim yet... The campaign also creates the greatest sense of playing a small but important part of a huge battle" *-PC Gamer*

"Thoughtful gameplay design and the effort to bring players a sense of the true fighter pilot's experience can be felt throughout the game" *-Computer Games Strategy Plus*

"European Air War combined huge dog fights, a great campaign system and realistic physics to make a game that was very hard to put down"
-IGN PC.com, Sim of the Year

"The care and attention to detail that went into every aspect of European Air War, from the hefty manual to the bomber nose art, represents a serious achievement"
-CNET GameCenter

THE KILLS!

"Bottom line: this sets the new standard in flight sims"
-Washington Post

"Falcon 4.0 is an incredibly detailed simulation that in many ways exceeds training systems in military use."
-Computer Gaming World

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JUERGEN REUDTEL

by Andrew Lawler

An Air Force expedition braves the Mongolian winter to study some highly unusual weather: meteor showers.

Night of the Shooting Stars

The drive to camp is a two-hour, teeth-jangling ride across frozen ditches and ruts, our Russian jeep squeezing through narrow mountain passes, then roaring over barren plains. We turn into a wide valley, and three domed tents—what Mongolians call gers (rhymes with "cares")—materialize slowly against the snow, black smoke curling out of their bright aluminum chimneys. The driver cuts the engine, and Air Force Colonel Pete Worden jumps out, zipping his olive-green parka in the subzero breeze. "Welcome to the U.S. Ger Force," he says with a grin, lighting a cigar.

The Mongolian steppes have seen countless invaders, from the native hordes of Ghengis Khan to Soviet armored divisions, but this could be the strangest military operation in the nation's long history. Worden is a Pentagon space strategist commanding an expedition of U.S. Air Force officers and Canadian scientists here to count shooting stars. More precisely, their purpose is to monitor the annual Leonid meteor shower and test an automated system that would warn satellite operators if the shower turns into a heavy storm that could harm spacecraft. Since the eyes and ears of the Pentagon are largely based in space, any threat to the 100-plus U.S. military satellites in orbit is a threat to be taken seriously.

How seriously is a matter of debate. Many researchers roll their eyes at the idea that meteor showers are a significant problem for orbiting satellites. The dangers posed by human-made debris or simple technical snafus in the cold and airless environment of space are far more worrisome, they say. "The meteor threat to satellites is a red herring," scoffs Don Yeomans, an astronomer at NASA's Jet Propulsion Laboratory in California and an expert on the solar system's small bodies.

But Worden is no fan of conventional wisdom, and he's willing to go to the end of the Earth to prove a point. With the help of a young Canadian astronomer, he has coordinated a campaign to bring the Leonid threat to the attention of higher-ups in the defense department. Worden is, after all, the Air Force deputy for "battlespace dominance," whose job is to ensure superiority in space and a continuous flow of data from satellites.

Worden's current enemy is a dirty snowball named Comet Tempel-Tuttle, which in early 1998 swung around the sun and passed through Earth's orbit for the first time in nearly 33 years, leaving behind a fresh trail of dust and grit. That means for the next two or three years the usually mild November Leonid shower could turn into a full-fledged storm. So with the help of Peter Brown, a University of Western Ontario doctoral candidate in astronomy who specializes in the arcane science of meteor streams, Worden has set up two sites in Mongolia to monitor Tempel-Tuttle's debris using optical telescopes, plus a third site in Australia that will use a sophisticated radar to track the shower particles.

Worden's meteor watch is one of many planned for the height of the storm. A team from the Dutch Meteor Society, for example, is joining colleagues from the Purple Mountain Observatory in Nanjing, China, to observe from a remote desert location and another site in the wooded hills around Beijing. NASA, the National Center for Atmospheric Research, and other partners are mounting an airborne campaign to study the shower from an instrument-laden L-188C Electra owned by NCAR and from a modified NKC135-E used by the Air Force for infrared observations. Both will take off from Okinawa and remain in the air over the East China Sea for six to eight hours.

Predicting exactly when and where the best viewing conditions will prevail is something of an art, and each team has had to consider both science and logistics. Brown's calculations show that the Asian side of Earth will plow into the densest portion of the debris during the night of November 17. At that time of year, much of South Asia is covered by monsoon clouds. But Mongolia, which is squeezed between Russia and China, offers some of the clearest skies in the world. And given that this is an Air Force-sponsored venture, Worden decides that taking the necessary tracking equipment into either Russian Siberia or northern China presents bureaucratic hurdles he doesn't need. The Mongolian government, once a staunch ally of the Soviet Union, now welcomes Westerners and is eager for contact with the United States. So Mongolia it is.

DANIEL FISCHER

Mongolia's stark landscape is empty except for the occasional nomad's tent, making it the perfect spot for viewing the Leonids (opposite) last November.

The primary base for the expedition is the country's decaying national observatory, located high above the capital city of Ulaan Baatar but still within a perilous bus ride of the relative luxury of heated hotel rooms. The second site, however, is in the remote valley far from town, where a small team will live in gers for a week. It's November, and the temperatures at night hover around 30 degrees below zero. On bare skin, even a light breeze is unendurable for more than a few minutes.

We arrive at the remote camp on November 14, three days before the Leonids are due to peak. That night and on each of the next several nights, team members bundle up and trudge outside to set up a half-dozen cameras to monitor the meteors. The low-light video system uses an image intensifier and charge coupled device (CCD) sensors to capture faint meteor trails in small squares of sky so that the scientists can get a statistically valid sample from which to determine the number of meteors and gather data on their masses, altitudes, paths, and speeds. Meanwhile, in Australia, a radar scans the sky more broadly, providing complementary information on the number of Leonid particles smashing into the atmosphere.

Data from both Mongolian sites and from Australia are transmitted via an INMARSAT communications satellite to Brown's university in Canada for processing, then routed to Schriever Air Force Base in Colorado, where they are posted on a Web page accessible to military, civilian, and commercial satellite operators who have the password. If a storm does blow up, Air Force operators are standing by with a 245-page plan detailing what steps to take—such as reorienting a spacecraft so that delicate solar panels don't face the oncoming rain of dust or powering down some of the satellite's systems to avoid electrical interference from the particles whizzing by at a hundred times the speed of a bullet.

The equipment in Mongolia is a prototype of Worden's ultimate vision—a low-cost automated system that could, with minimal human supervision, serve as an early warning system during intense meteor showers. His goal on this trip is to show that the whole operation, from setting up cameras in a remote and hostile location to delivering high-speed data via satellite to Colorado, works as advertised.

It's just the sort of unconventional project that the Air Force colonel revels in. Worden has made a career of trying to boost the Pentagon's interest in space, with mixed success. As a deputy for technology in the Ballistic Missile Defense Organization, he pushed for a fast and cheap Department of Defense mission called Clementine, which in 1994 found evidence of water at the moon's poles but failed in its main objective, meeting up with an asteroid. Clementine was bitterly opposed by

some in Congress and at NASA, who felt the DOD had no business venturing onto the space agency's turf. As a staffer on Vice President Dan Quayle's space council from 1989 to 1991, Worden also played a behind-the-scenes role in pushing a reluctant NASA to reinvent itself as a leaner, nimbler organization. And he was a strong supporter of a space-based anti-missile defense system, an idea that by the early 1990s was forced to retreat under fire from its many critics but that has never entirely gone away.

"Pete is a revolutionary," says Mark Albrecht, an aerospace executive with Lockheed Martin who directed the space council under Quayle. "He has zero tolerance for bureaucracy, and he will use any tool to move his vision forward." As a result, Worden generates a loyal cadre of followers as well as plenty of enemies. "If you believe in his vision, he's a champion," says Albrecht, "but if you don't, he's as black and evil as can be." Critics and friends alike call him Darth Vader.

Worden's latest passion is protecting the fleet of reconnaissance, missile-warning, weather, and eavesdropping satellites that have become increasingly vital to U.S. military commanders in the field. Imagery from spy satellites, for example, has been used to select bombing sites during operations in Iraq and Yugoslavia. The Air Force recently set up a Space Operations Center at Vandenberg Air Force Base in California to act as a nerve center for all its space data, and to cope with any threats to satellites. Worden is convinced that the Leonids could become "a real-live threat," so he talked his Pentagon superiors into coughing up about half a million dollars for the Mongolia-Australia expedition, with the idea that his system could deliver early warnings of trouble in space.

For Brown, the Canadian scientist, the Air Force interest means a source of much-needed funding in a field that receives scant attention in the scientific community. "I don't make any pretense about my deep interest in the effects of meteors on satellites," he admits on a bumpy ride through Ulaan Baatar's potholed streets. "I'm not an engineer. But the fact is that there aren't large amounts of money to do meteor research, because there's no major constituency." Now Brown has enough support to study the dynamics of meteor streams to his heart's content.

JOHN CHUMACK

New Mexico, Nov 17 3:51 am

In A.D. 902, not long before Ghengis Khan and his horsemen swept down on them, Chinese astronomers noted what looked like a rain of stars on a mid-November night. Nearly a millennium later, in 1833, New Englanders ran from their houses to watch tens of thousands of meteors falling like bright snow from the heavens. And on a chilly November night in 1966, high in California's San Gabriel Mountains, a handful of meteor buffs were rewarded with a spectacular display of about 150,000 meteors an hour streaking across the sky.

Debris particles left by Comet Tempel-Tuttle are generally not much bigger than grains of sand. During a typical Leonid shower, which lasts a few days, they burn up in the atmosphere at the rate of a dozen or so every hour. But predicting a large storm like those that occurred in 1833 and 1966 is notoriously difficult. A subtle tug by Jupiter or a crumbling of material on one side of the comet as it rounds the sun can shift the debris trail enough to cause Earth to miss it entirely. Forecasting the intensity of a meteor shower is like trying to guess the number of raindrops that will fall in a thunderstorm.

Until recently, the question of how many meteors would appear in a given year was of interest to only a handful of researchers and enthusiasts. The large Leonid storm of 1966 came at the dawn of the Space Age, when fewer than 100 satellites—with electronics that would be considered clunky today—were in orbit. But as the number of spacecraft has passed the 600 mark, and as their technical sophistication and importance to global finance, communications, and military operations have grown, a few researchers and satellite operators have started paying more attention to meteor hazards.

In 1993, a European Space Agency research satellite called Olympus went dead. The likely culprit, according to an investigative panel, was a meteoroid. Until then, such natural particles were considered far less of a threat than orbiting junk—spent rocket parts, paint flecks, and other man-made debris that routinely pings the windows of the space shuttle and pocks the hulls of spacecraft like the Russian Mir station and the Hubble Space Telescope.

"A grain of table salt could punch a hole in a satellite," says Air Force Master Sergeant Terry Rich, a spacecraft

operator who helped prepare the service for last year's Leonid shower. That's because the collision typically happens at tens of thousands of miles per hour. Worse, the damage may not be limited to a puncture—the impact of a speeding particle can cause an electrostatic discharge that would fry sensitive electronic components. Though military satellites typically are hardened to withstand the harsh space environment, it's too expensive and impractical to shield all spacecraft from meteoroids or other fast-moving objects.

The faster the particle, the more damage it can do, which is why Tempel-Tuttle's return to the inner solar system had people like Worden and Rich worried. While most meteors poke along at about 40,000 mph, the angle of the Leonid swarm relative to Earth's orbital path causes the particles to pass through the upper atmosphere at nearly four times that speed.

So Rich and other satellite operators went to work assembling a plan for protecting Air Force property in the event of a big storm. The strategies include turning a spacecraft into the wind—that is, reducing its cross-section to minimize the chances of a hit, as well as shutting down unnecessary onboard electronics. A postmortem investigation of the Olympus failure concluded that a meteoroid had hit an exposed wire extending from the solar arrays into the satellite's interior. The resulting charge surged into the spacecraft's innards, damaging vital systems. According to Congressional testimony given last year by William Ailor, director of the Center for Orbital and Reentry Debris Studies at The Aerospace Corporation in Los Angeles, had Olympus been oriented edge-on to the incoming particle, or had it been in a standby mode with some of its onboard systems powered down, the damage might have been avoided.

Some satellite owners have already started taking such precautions. NASA pointed the Hubble Space Telescope's delicate optics away from the meteor stream during the 1993 Perseid shower, and the agency avoids launching space shuttles during these brief periods. But the Pentagon is understandably nervous about decommissioning, even for a few hours, a satellite that is supposed to be on constant lookout for missile launches or troop movements.

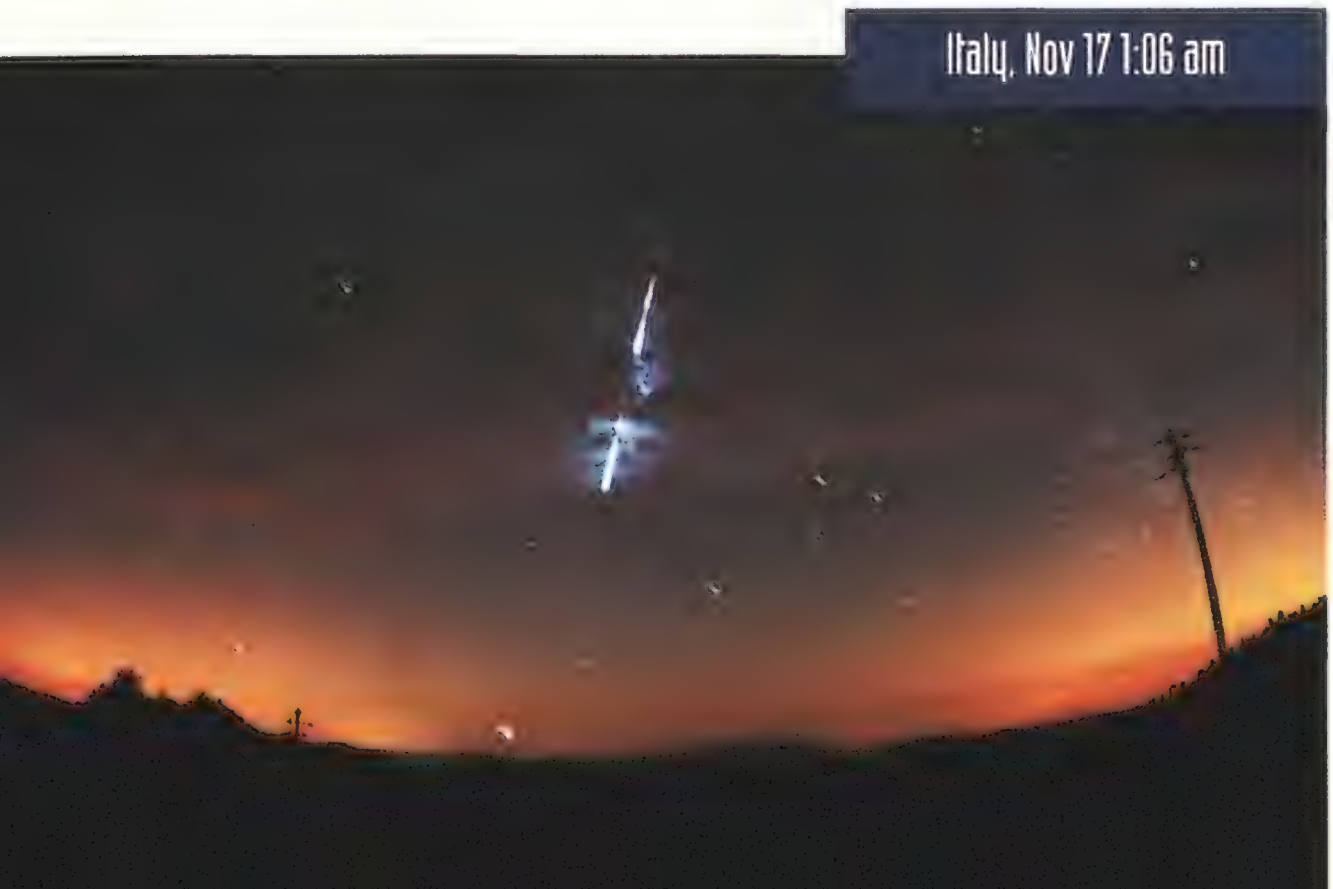
In 1993, the year Olympus died, Peter Brown received a call from an Air Force major with the National Reconnaissance Office, the secretive organization that operates the military's spy satellites. He had come across the Canadian's name while gathering information on the danger of comets and asteroids striking Earth. Growing up in northern Alberta, Brown had taught himself skywatching and had carried that interest on to college. Now, as a graduate student in physics at the University of Western Ontario, he was doing research on the meteor streams left by comets like Tempel-Tuttle.

The major's phone call introduced Brown to the twilight world of spy satellite specialists. Those contacts led in turn to an April 1997 Leonids workshop in Colorado sponsored by the Air Force's 55th Space Weather Squadron, which keeps track of solar flares, meteor showers, and other events that might disrupt satellite operations.

On the first morning of the workshop, Brown linked up with Worden, who was just moving into his new Pentagon job after commanding the base at Schriever for a couple of years. They make an odd couple. Brown is a strapping 28-year-old with curly brown hair and a brash and talkative manner. Worden, with flat black hair continually falling in his face, mumbles in short, rapid bursts and is two decades the Canadian's senior. He was already working as a policy wonk in the Reagan-Bush White House when Brown was in junior high school. But the two share a love of space exploration, and by the end of the week-long workshop Brown was nearly as gung-ho as Worden. "We would drink single-malt Scotch at night, then be up working from 6:00 a.m. on," Brown recalls. Worden introduced him to the generals at Air Force Space Command and showed him Cheyenne Mountain, the underground complex outside Colorado Springs that controls the U.S. air and space defense network. He also helped Brown navigate complicated funding channels and land contracts with NASA and the Air Force.

The civilian space agency, meantime, was not especially worried about meteor showers. With fewer satellites in orbit and a more scientific bent, NASA was interested more in the composition of meteoroids and the role they may have played in seeding Earth with the carbon-based building blocks of life. So the agency focused its 1998 Leonid efforts on the airborne mission over Okinawa, and turned down Worden's invitation to be a full partner in the Mongolia expedition.

Undaunted, Worden and Brown assembled a team at Edwards Air Force Base in California to monitor the 1997 Leonid shower as a dry run for the return of Tempel-Tuttle a year later. Meanwhile, the Air Force Space Command organized satellite "anomaly resolution" teams made up of spacecraft contractors, engineers, and operational personnel to work out a strategy for dealing with a heavy assault from meteoroids.



LORENZO LOVATO

MOHAMMAD ODEH, JORDANIAN ASTRONOMICAL SOCIETY

According to the plan, they would rely on data gathered by the Mongolian and Australian expeditions—the first time information on meteors would be supplied to satellite operators in real time.

At the remote site in Mongolia, Worden stalks around, checking out the spartan accommodations that will be home for a team of six Air Force officers and Canadian scientists for the next week. Brown picked the site the previous summer, while it was still green and lush. Now the valley is as stark as Mars, with no trees or bushes or even so much as a tuft of brown grass poking through the snow. Only a few nomadic tents suggest a human presence. Snow-capped mountains loom to the east. The altitude—nearly a mile above sea level—and the cold, clear air promise good viewing.

Worden has brought flags and cigars. Not just a U.S. flag, but flags from the Secretary of Defense's office, from the Air Force, from the National Reconnaissance Office, and from NASA, which is contributing a little bit of money after all. One of the Canadian astronomers has brought his country's red maple leaf banner, and all are hung together outside one of the gers. Expedition team members take turns posing and clicking away with their cameras in the fading light. Then everyone crowds through a small painted door into the dim light of one of the small circular tents for bowls of mutton stew, the national meal, which is cooked on a small wood stove in the center of the ger.

The big worry is that on the peak night, November 17, clouds could move in, depriving the researchers of data. Worden and Brown have hatched an elaborate and risky contingency plan to ferry scientists further south into the Gobi Desert if necessary, using two massive Soviet helicopters owned by the Mongolian army. Only a select few could make the trip, since everything from a generator to computer equipment to food and water would have to be squeezed into the helicopters.

It's a scenario nobody likes. "People are going to be bone tired by then, and tired people make mistakes," warns Alan Hildebrand, a University of Calgary geologist famous for pinpointing the crater from the meteorite believed to have killed the dinosaurs. Someone dubs the idea "Operation Hell." Worden hears out the group, then jumps back into the Russian jeep for the trip back to Ulaan Baatar. He and Brown spend the next few days at the observatory site preparing for the big night.

But the peak appears to begin a day early, on November 16. Violet-headed fireballs with green tails explode across the sky, lighting up the snow-covered landscape. The temperature is approaching 30 degrees below zero and the sky is clear. At the remote site, the usually taciturn scientists are ecstatic. "Awesome, just awesome," cries Hildebrand. Scientific detachment falls away and the researchers whoop like kids. The data—a video display of white streaks across the black sky—flows smoothly from the observatory and the remote site to Canada, then on to Schriever. But while the fireballs, which are being seen all over the world, are dramatic, they are "irrelevant," says Brown. Satellite operators know the real danger comes from large swarms of smaller particles, not from a few big ones.

Still, the fireballs seem to presage an impressive and potentially dangerous peak the following night. On the evening of the 17th, with skies clear and no clouds in the forecast, Operation Hell is officially canceled. Mongolian, European, and U.S. reporters crowd the oddly Spanish-style building at the national observatory, while Mongolian researchers and officials mill about. In the center of it all are Worden and Brown, giving interviews, chatting with local dignitaries, and checking in with astronomers who have set up an observation platform on a small deck with a wide view of the sky.

There are meteors, but the shower tonight proves modest, hardly the storm that Brown and others had predicted. Good news for satellite operators but a disappointment to the astronomers, and a bust for the media crowding the corridors. Worden and Brown put on their best faces. "This was no big storm, but I was aware from the start that this is a crap shoot," Brown says later. "Negative observation is good too, and every year we will build a little more understanding of the Leonids."

At the remote site, a nightmarish series of events has befallen the Canadian researchers. Hildebrand and Bob Hawkes of Mount Allison University in New Brunswick, who is the group's expert on video recording of meteors, had been in high spirits as they prepared for the peak of the storm. Now, after months of planning the complicated logistics, everything seems to be in proper order—the computers and cameras and telescopes all wired together and activated, thanks to a noisy gasoline generator in the gulch outside the ger.

Then the satellite phone suddenly goes on the blink. It, of course, is critical to feeding real-time data to Colorado. The only solution is to send someone to town to find a replacement. But in a land of no antifreeze and subzero temperatures, one doesn't just jump in a truck—particularly an ancient Russian one—and go. You first boil water to fill the radiator, cover the open hood with a tarp, and finally apply a blowtorch to the surrounding air to warm up the engine. Unfortunately the blowtorch, left too close to the roaring stove in the sleeping ger by one of the support crew, explodes before it can be used on the jeep, sending flames into the sky and jolting Hildebrand out of his preparations. He rushes up as two Mongolians fly out of the burning tent. Once the fire is out and he has dressed

the wounds, which prove miraculously minor, Hildebrand rushes back to the instruments. By now it's too late to find a replacement phone in time. The real-time link is out of the question, although the team is still able to record data for later analysis.

No matter—few meteors show up. "Why is it so dead?" Hildebrand asks despairingly at midnight. At about 1 a.m., Hawkes returns half-frozen and puzzled from a long watch outside, having counted no more meteors than you could see on any clear night.

At 3 a.m., the tough and normally stoic Hildebrand breaks into laughter at the absurdity of the team's predicament, laughter that brings tears to his eyes in the cold air. By 6 a.m., everyone is thoroughly dispirited and ready for sleep. That's when the guests unexpectedly show up—a retinue of parliamentarians and distinguished Mongolian scientists. They're eager to see the meteors, meet the foreign researchers, and tour the camp. More guests, we're told, are on the way. "The president and prime minister should be here by now," the interpreter says. "Have they not arrived?" The exhausted Canadian scientists eye one another in dismay.

After giving an abbreviated tour, Hildebrand and Hawkes go to bed as dawn arrives. The guests continue to toast the non-storm with Genghis Khan vodka until the sun is well up in the sky. The president and prime minister never show up—apparently they got lost, a common occurrence in a land of few paved roads and virtually no signs.

There's no evidence that any satellites failed or were damaged as a result of the 1998 Leonid shower. Brown admits that he overestimated the intensity, but says that his preliminary analysis of the data shows "conclusively" that the 1999 Leonids will surpass last year's event. If not, there's always 2000. History suggests that he may be right: After the 1899 storm failed to live up to expectations, few observers stayed up to witness the impressive 1901 event.

Why were his 1998 models wrong? "I know everybody will say this is just spin, but I need observations—and I can only get them once a year," he says. "Every year we build a little more on Leonid understanding." Every year, he says, he grows more confident in the data and in his models.

A number of academic and NASA critics remain unconvinced that a Leonid alert system is worth the time, effort, and money. Some see a greater threat from solar flares, which already have damaged several spacecraft, and say that increasing the reliability of spacecraft would be a better investment than charting meteor streams. "Think design improvements to thermal wave tubes or attitude control systems," says one specialist. "If you roll together the meteor, orbital debris, and even the solar event threats, it's only a small part of the risk" that comes with operating a spacecraft in orbit.

Such criticism doesn't bother the thick-skinned Worden, who chalks it up to NASA's mission being different from that of the Air Force. He's already busy planning the 1999 expedition, which could be to Israel's Negev desert or to Ellesmere Island in the Canadian Arctic. He says his Pentagon backers were happy with the Mongolian-Australian expedition, despite the mixed results. "We were very cautious about this," he says. "We didn't sell a lot of wolf tickets." The continued Air Force support signals what Worden calls "a growing concern" about the vulnerability of military spacecraft.

Brown sees his own meteor work going far beyond mundane concerns about the health of satellites. "When we go into deeper space—say to Mars—we will need to know about meteoroids," he says. "It's the natural stuff in the interplanetary shooting gallery, and that's where we're stuck." Which is why, when Pete Worden heads off next November to some godforsaken spot or another to count Leonids, Brown is likely to be right there by his side.

RICK HE


N4068W

Drugnet

If you're flying narcotics into the United States, the eyes of U.S. Customs are upon you.

by Joseph Bourque

Photographs by Erik Hildebrandt

"NOWHERE TO RUN...NOWHERE TO HIDE." The motto glints from a coffee mug near the radar console in this Lockheed P-3 AEW (airborne early warning) belonging to the U.S. Customs Service. The aircraft, called a Dome because of the large radar antenna housed in a 24-foot-diameter disk on its back, is the patrol car on a beat covering the eastern Atlantic and the entire Caribbean basin. That's a lot of ocean, but the Dome's AN/APS-138 radar is a lot of radar. "One megawatt—a million watts of power," says Reldon Leininger, one of three radar operators aboard, gesturing vaguely toward the antenna's location. "It can look at nearly 200,000 square miles of our search area in a single sweep." Leininger is a cheerful, burly man, and, despite long, sometimes dull missions, finds his task of sifting through symbols on the radar screen absorbing and, in a way, fun.

Today we're headed for the Bahamas, and for the next 10 hours we'll be looking for pilots who smuggle narcotics by air. Although the Customs Service is charged with preventing the importation of anything illegal, from stolen parrots to pirated software, the four AEW aircraft routinely deployed from the Surveillance Support Branch in Corpus Christi, Texas, are flying because of the intense public attention focused on drugs.

Leininger shows me the screen where numerous symbols represent aircraft and ships; the area around Florida and the Keys is a very busy place. But where I see confusion, an experienced operator sees information. "A circle is a surface target, a square is an airborne target, and an inverted V is a hostile," says Leininger. "The colors are also significant. Green is friendly, yellow is unknown, and red is hostile." The radar's computer interprets the codes squawked by aircraft and ship transponders and displays them as colored shapes. Each shape is accompanied by information on speed, heading, and altitude. Blue dots underneath the shapes are raw radar data, objects the radar has seen but has received no code from. Most represent legitimate commercial, military, or general aviation traffic. What we're looking for is the anomaly: an aircraft that's going low and slow, one that deviates from its flight pattern, especially if it begins to meander or circle, one that makes significant changes in altitude when it's nowhere near an airfield.

Our own P-3 AEW is at this moment a green square on another radar screen at the Domestic Air Interdiction Coordination Center in Riverside, California. Recently upgraded with a Silicon Graphics Power Challenger computer system, the center is, say its operators, the most sophisticated radar tracking center in the world. The computing power is almost palpable in the operations room, where huge screens on the walls are illuminated with radar tracks of the air traffic in the southern United States and south of the border, extending to South America. The system is capable of handling up to 12,000 radar tracks at one time.

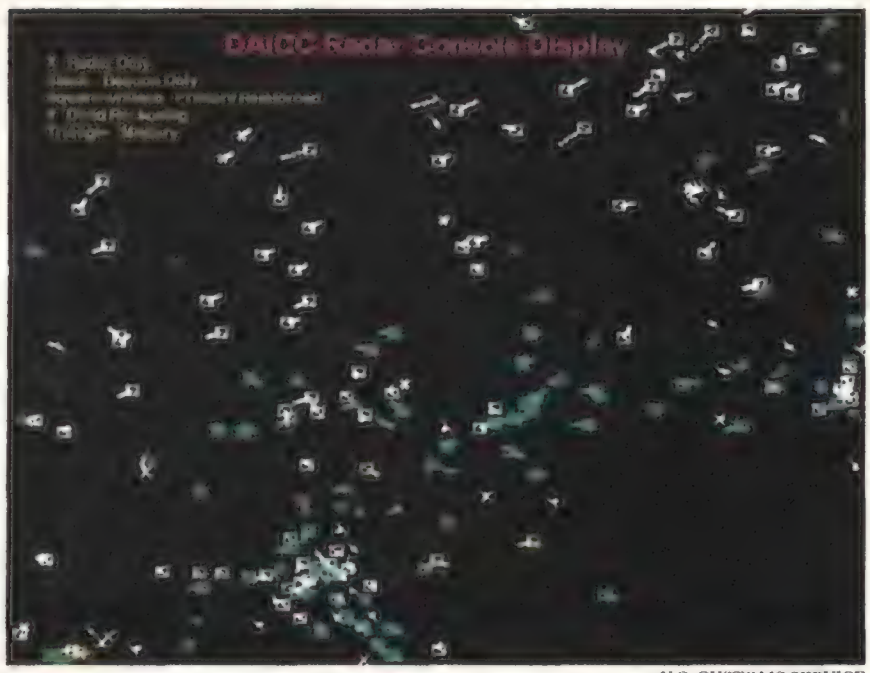
A fusion processing system receives data from 70 radar sites: air traffic control centers, naval air stations and military bases, and other land-based radar installations, including two in Venezuela, two in Colombia, and an array of aerostats (tethered radar blimps) along the Mexican border. The computer combines the information with a digital map and displays a coherent single picture for any geographical area selected by an operator. In short, detection specialists sitting at these consoles can see virtually every aircraft in the air between the north coast of South America and New York, and from the Bahamas to Baja. If they see something fishy, the DAICC will launch aircraft to check it out—most frequently, a Cessna Citation II from the U.S. Customs Miami Air Branch in Homestead, Florida.

Some of the smugglers wanting to get through have learned where the ground-based radar sites are and how to circumvent them, and therefore may not show up on the Riverside consoles. For them, there's Reldon Leininger and the P-3 Dome. Its 14-hour mission capability and long range are a match for smuggler airplanes outfitted with extra fuel tanks. Leininger was on a mission in 1996 that tracked a Cessna Caravan all the way from the Caribbean up the east coast of the United States and into Canada, where the apprehension phase—"the end game," as Customs agents call it—was handed over to Canadian authorities. Seven men and one woman were arrested. It still stands as the longest surveillance mission flown by Customs aircraft—15 and a half hours, including a refueling stop in Bermuda. Says Leininger: "We were too tired to fly back to Corpus Christi, so we overnighted in Maine. It was cold up there and we were wearing shorts."

With a video camera under its nose, a Eurocopter AS 350D AStar gives Customs' Miami Air Branch a Big Brother's-eye view of south Florida.

The Dome is one of the more effective weapons in a cat-and-mouse game in which the mouse has frequently had more resources than the cat. Congress authorized a Customs Air Interdiction Program aimed specifically at drugs in 1969, when it became obvious that major air smuggling routes were firmly established along the southern U.S. border. In the beginning of the program, according to agents who were around then, neither the criminals nor the cops chasing them were very sophisticated. "Smugglers would go rent an airplane under an assumed name, throw a waterbed mattress in the back, fill it with gasoline, and run water hoses from it through the wing spars to the wing tanks," recalls Russ Manhold, who joined Customs in 1971 and is now operations manager at the Miami Air Branch. "They were long-range flying bombs. The holes they drilled in the spars ruined the airplane, but they didn't care. They'd make a run down to Colombia and back, then abandon the airplane." Without the radar coverage that Customs has today, smugglers easily flew across the border. Remote areas in every state across the South were littered with abandoned or crashed airplanes.

Air interdiction at the time depended on a sparse crew of pilots flying a motley collection of helicopters and small airplanes, most of them seized from drug smugglers. Terry White, a pilot with the Miami branch, also joined Customs in 1971, and remembers that the police work consisted of low-cost undercover operations. "We'd go out to these small airports posing as airport bums and help people out fixing and fueling their airplanes," he says. "We knew what time they left, how long it took to get to Colombia or Belize, and how long they'd be on the ground, so we knew when they'd be coming back. They never came back to the same airport, but usually the same area. Sometimes we were able to get a court order to wire in a transponder, so if they came back over an area with radar, like New Orleans, we'd get a heads-up. We'd chase three or four aircraft every week, all small stuff.



U.S. CUSTOMS SERVICE

The forward-looking infrared sensor on a Customs Citation shows the instrument operator a TV-like image (top). But the big picture appears on consoles at the Domestic Air Interdiction Coordination Center in California.

"It was like a Wild West show," White continues. "People running off runways and running everywhere. On one occasion, one of our aircraft was following a smuggler at night. Nobody had lights on. When the bad guy landed, his people heard the other airplane behind him and shoved a [Ford] Crown Victoria out onto the runway. Wiped out our airplane. Then the pilot had to shoot it out with the bad guys on the runway. Lucky he wasn't killed."

And drugs poured into the country by air. "Bales of coke and marijuana were falling out of the sky over Florida," says Joe Maxwell, the director of the DAICC in Riverside. Maxwell came to Customs from the Drug Enforcement Administration in 1977, when law enforcement agents felt they had too few resources to use against the flood of drugs. But the tide was about to turn, and Maxwell cites a Stanford Research Institute study, completed in the early 1980s, as one impetus for the change. The report estimated the number of flights smuggling drugs into the country at 6,700 a year. "We took that information to Congress," he says, "identified what we'd need, and they funded it."

Aerostats—tethered at 10,000 to 14,000 feet—went up along the Mexican border, in Key West, and in the Bahamas starting in 1985, and the Customs Service got a fleet of aircraft to perform interdiction operations: surveillance, tracking, and apprehension.

For surveillance, a pair of P-3s patrols almost daily: a Dome and a second P-3, called a Slick. The Slick carries no radar antenna on its back (thus: "Slick") but has in its nose the same intercept radar used in F-15 fighters. Although they can work alone, the P-3s are most effective in pairs, the Dome looking far and wide and the Slick locking on and trailing whatever target the Dome finds. Four of each are stationed at the Corpus Christi branch, and four more of each are authorized.

For tracking, the Air Interdiction program has 26 Cessna Citation II jets. The Citation can sprint to a target at more than 400 mph; it can also fly at around 100 mph to follow the single-engine and light twin-engine aircraft smugglers frequently use for flying low and slow. Though the number varies, the DAICC

will launch as many as three or four aircraft a day, according to DAICC director Joe Maxwell.

For apprehension, several of the nine Customs air branches are equipped with Sikorsky UH-60 Black Hawk helicopters, each able to carry six armed officers and extra gas for extended range and still get to its target at 200 mph.

This combination has worked well enough to virtually stop direct penetration of U.S. borders by smuggling aircraft. According to U.S. Customs data, in the 10 years between 1982 and 1992, the number of smugglers crossing the border by air fell by 92 percent.

So the smugglers adapted. They began landing short of the border—in Mexico, where the Black Hawks couldn't go—and breaking up the loads for shipment across the border hidden in cars, trucks, and human "mules." Says Matt Hutto, a supervisor at the Corpus Christi surveillance branch: "About 1992, we began realizing that we were leaving a big hole open in the west, so we negotiated permission to fly over Mexico, toward Baja, and found a gold mine. We'd been dealing with smaller planes, but now we were seeing Turbo Commanders, Super King Airs, Aero Commanders—much larger, more expensive aircraft." Smugglers would form up as many as 10 of these aircraft in a caravan, each 20 minutes behind the other, and stream up the west coast of Mexico to land short of the border.

"When we started nabbing too many of their King Airs," says Hutto, "they tried to ship more in a single load with a faster airplane they thought would outrun us. They bought old Caravelles and even 727s that the airlines wouldn't touch. They'd put six or seven tons of cocaine in them and fly them into Mexico, near the U.S. border. Did that for about a year. A dozen times or so. That experiment didn't work very well. It's too hard to hide a 727, even in Colombia, and they had too many problems with planes as beat-up as those were." So the smugglers shifted the aircraft-to-land transfer points from Mexico to Central America, and Customs, while still maintaining a screen across the southern U.S. border, began contributing some of its P-3 capabilities to U.S. interagency task forces already working in Central and South America.

The Customs Service is joined in the fight by the Coast Guard, FBI, FAA, CIA, IRS, DEA, the Bureau of Alcohol, Tobacco, and Firearms, the Border Patrol, and the Department of State, as well as each state's National Guard and Air National Guard, Civil Air Patrol, and hundreds of regional and local law enforcement authorities—and, since 1988, all branches of the military. Of the $17.9 billion administered by the White House Office of National Drug Control Policy in 1999, a little more than $2 billion is spent on interdiction. The Customs Air Program gets $176 million of that and has primary responsibility for the U.S. border, up to 100 miles out, referred to by drug enforcement types as the Arrival Zone. Customs shares air interdiction responsibilities with the Coast Guard in the Caribbean and the areas adjoining Mexico and Central America—the Transit Zone, where the Department of Defense helps out with monitoring and intelligence operations, including helping to staff two Joint Inter-Agency Task Force radar centers, one in Panama and another in Key West. In 1998, according to the White House

Wearing its surveillance hat—a powerful AN/APS-138 radar—a P-3 Dome waits in Texas for its next prowl.

MARK J. VYRROS

Office of National Drug Control Policy, a total of 88 tons of cocaine was seized in the Transit Zone.

The prosecution of the "drug war" has not been without bureaucratic wrangling, and one of the still sensitive areas is the decision made by the defense department in 1994 to dismantle the aerostats in the Bahamas. The military had decided they were archaic technology and replaced them with a radar system called ROTHR, for Relocatable Over The Horizon Radar. "It works great but it's like a flashlight," says Russ Manhold. "Unlike the overlapping aerostats, ROTHR only shows you what it's pointed at. Right now it's looking mostly in the transit zone down by Central America." The single aerostat in Key West operates only three days a week, weather permitting, because the National Security Council decided to share that site with a blimp-borne TV antenna broadcasting Voice of America-type programming into Cuba.

So a lot of the drug smuggling action has shifted back to the Bahamas and the surrounding area, as close as possible to the Florida coast. Light twins and even singles are back in favor, but the new tactic is air drops. Manhold continues: "An airplane from Colombia will cross over central Cuba and drop its load into the water just inside the Cuban ADIZ [Air Defense Identification Zone], where we can't go. With the infrared systems on the Citations and the Slicks, we can even see the bales drop. Then the airplane turns around and goes right back to Colombia."

In response, the surveillance support branch regularly lends its P-3s for temporary duty in Central and South America. Those operations are highly secretive. I was booted out of a briefing on South American operations. For a routine patrol over the Bahamas, however, I was welcomed aboard.

On the P-3 flight that I accompany, an air drop is what we all expect to see, if anything. Instead, we meander around the Bahamas for 10 hours, picking out occasional targets that eventually turn out to be legitimate. I watch the radar for what seems a long while, then go back to get my frozen dinner out of the refrigerator and pop it in the microwave. Then I go back and watch the radar some more. Then I go back to get a pop. Radar. Apple. Cockpit. Radar. Cookies. Radar. Cockpit. I'm in the jump seat and watch the landing. Smooth. Midnight. Sleep.

A few days later, there is slightly more action on a flight with the other half of this "Double Eagle" surveillance team. I'm in a Slick taking off from Corpus Christi, headed back for the Bahamas. (Our teammate, the Dome, will take off later.) The Slick is piloted by 41-year-old Larry Townsend, who, like nearly all P-3 crewmen, got his training in the Navy. Before takeoff, Townsend gives me a brief tour of the aircraft. I appreciate the sheer brute power of the AEW radar, but the Slick has more interesting toys. While its F-15 intercept radar sees only 60 degrees on either side of the nose, it's ideal for tracking at close quarters. The Infrared Detection System, which senses the heat objects generate, produces what looks like a black-and-white television picture, and it is especially effective for seeing targets at night. It can pick up a target as far as 80 miles away, but it is most effective within 40 miles.

The most interesting equipment on board is the gyro-stabilized optical telescope, which looks out of a special bubble window made of very expensive glass on the left side. The operator sits at a console with two screens, one showing a long-range view with a moveable box-shaped cursor that can be positioned over a target with a joystick. Whatever is inside the box shows on the other screen in close-up view. The operator can read foot-high tail numbers on an aircraft eight miles away. In this integrated system, the telescope can be slaved to the infrared, which can be slaved to the radar, so that any radar target can be made instantly visible to the other two operators.

Better yet, the Data Transfer System console, where I'm sitting for this mission, can access information from all three, as well as from the navigation system. It's a Windows-based computer on which I can display a moving map showing our position and track. I can also show whatever image is currently appearing on either the radar or the infrared. And I can show what the telescope operator currently sees. Or I can display all four at once in different quadrants. In addition, this terminal can capture any image showing on its screen and transmit it by satellite to any appropriately equipped aircraft or ground station.

Despite this system's formidable capability, it's sometimes more efficient at close range to use visual cues, so there is a gunsight device mounted in the pilot's left window that's connected to the infrared. I'm invited to try the gunsight. I pick a tiny speck on the water several miles away and use my right

The Sikorsky UH-60 Black Hawk can race to a crime scene with six armed agents. Although Customs crews train for such Miami Vice-type missions, recent crime scenes have been in the middle of the ocean, diminishing the helicopter's usefulness as a cop car.

hand to adjust the aircraft's heading on the autopilot as I manipulate the sight's controls with my left. To my surprise, I succeed very quickly. The infrared locks on, and a few seconds later the telescope has acquired the target, which turns out to be a sailboat with nothing suspicious about it.

But some time later, we get a call from the Dome; it has found an aircraft that might fit a smuggler profile. The target is not transmitting a transponder code and is doing 195 mph at 3,000 feet—within the "low and slow" parameters of a twin. We dash to the scene at 415 mph, then slow down to do the magic with infrared and telescope. The view screen shows a rounded nose somewhat like that of a DC-3, but none of us can identify it. If we pull up several miles to the right side of the aircraft, the left-looking telescope is pointing directly into the sun, and no manipulation of the contrast and brightness will show us the registration numbers on the right side of the aircraft.

After a bit of jockeying, Townsend says: "I guess we'll have to do it the old-fashioned way." So he maneuvers the P-3 behind the target and creeps up on it. From a couple of hundred yards away, the copilot tries to read the registration numbers with binoculars, but the light and angle are still wrong. Townsend creeps up to within a few feet of the tail and, by swinging just a bit to the left, can get a reading on the numbers, which he transmits to the DAICC in Riverside. It's a legitimate aircraft, an Embraer registered to a small cargo airline with no history of suspicious activity, so we just slip away without ever having been observed.

Jeff Houlihan, a senior detection systems specialist and former Air Force technician who spent five years at the North American Aerospace Defense Command (NORAD), frequently fields such an inquiry from a patrolling P-3.

Houlihan was on the Riverside Center's scopes when Cuban MiGs shot down two Cessna Skymasters belonging to the Brothers to the Rescue organization in 1996 and prepared much of the visual evidence—pictures of radar tracks and other data—for the White House.

Each console in Riverside has a second screen linked to more computerized data than we ordinary mortals are ever likely to imagine. Houlihan can conjure up mind-bending amounts of information on any registered aircraft: owner, age of the airframe, maintenance records, all flight plans ever filed for it, any records of illegal activity. He can also access a current flight plan (if one has been filed), so he'll know how many people are aboard the airplane, its flight track, points of origin and destination, proposed altitude, and speed. He can then set up a track on the screen representing the proposed flight plan and see how the actual flight deviates.

"As a law enforcement agency, we can gather information on U.S. citizens, which the military can't do," says Houlihan. "Our only boundary is the Constitution." He can find out how many times the owner has entered the country and where, who was aboard, and how frequently that aircraft comes into different ports of entry. And he has links or at least phone numbers for all law enforcement entities in the United States, right down to a one-person sheriff's department, and for many outside the country. The system also contains information from informants and even from ordinary citizens, who occasionally call in sightings of suspicious aircraft. Says Houlihan: "All those pieces of data gradually build into a profile of the target you're looking at on the screen, and you're that much closer to nabbing the guy who's stepping over the line."

If you judge by a couple of P-3 missions finding nothing on patrol, air interdiction seems to work. And yet reliable intelligence indicates that 475 tons of cocaine departed the Source Zone in 1997 headed for the United States by all available means, including container ships, go-fast boats, trucks, human mules, and many others. Two-thirds of that amount made it through. The drug cartels have developed more sophisticated methods of transporting—hiding drugs inside legitimate cargo on container ships, for example. In the measure-and-countermeasure pattern that has evolved in this area of law enforcement, Customs is now developing computer identification procedures and X-ray devices.

"It's like handling a balloon," says Joe Maxwell. "You grab hold on one end of the balloon and it bulges at the other end. You grab the other end, and it bulges somewhere else."

It's that shifty quality that opponents

of interdiction use to make the case against it. All of those billions of dollars spent on interdiction seem to make no appreciable difference in the amount of drugs available on U.S. streets. Regardless of the amounts interdicted—"We seize a lot of narcotics," Maxwell says. "I mean tons. Hundreds of tons"—the supply has been unchangingly adequate to meet the demand.

In late March, a Piper Navajo dropped about 30 bundles of cocaine into the ocean just north of Cuba and was apprehended in a textbook example of an interdiction. Detection specialists at the interagency radar center in Panama watched the Navajo emerge from government-restricted airspace in Colombia. They then notified the DAICC in Riverside, which directed a pair of P-3s and a Citation to track the aircraft. "The aircraft came across Cuba," says Russ Manhold. "As they always do," he adds wearily. "Our aircraft waited at the north of Cuba, and the Citation and a sensor-equipped Piper Cheyenne III observed an air drop, which took place within Cuban airspace."

At about 4 p.m., the Navajo dropped the cocaine to a go-fast boat waiting near Guinchos Cay in the Bahamas. And this time the airplane did not make the customary U-turn and head back to Colombia. It flew on to land at Andros

Bill Dailey heads the Miami Air Branch, where Black Hawk helicopters are on alert and every pleasure boat is a potential suspect (top).

Island in the Bahamas, then took off again and landed at Nassau International Airport, where, alerted by the Customs trackers, agents from a joint DEA-Bahamian police operation arrested the pilot and seized the airplane.

The P-3s then returned to the site of the airdrop and reacquired the boat, which had begun to head toward the Bahamas as well, and two Customs police boats came out from Miami and Key Largo to run the suspects down. Bill Wolfe, who was operating the AN/APG-66 radar in the Citation, had a ringside seat as the boats gave chase.

"I knew we had a good chance, once the Customs boats were out there," he says, "but I was afraid the guy would make it into the little bays around the Bahamas. We had perfect conditions; there was a moon which helped to find the wake. And we vectored the boats in. I could see one of our guys start to slowly, slowly, slowly close the distance, and then the other [Customs] boat just came shooting out of nowhere."

At about 2:30 that morning, Army Black Hawk and Coast Guard helicopters joined the chase and illuminated the go-fast boat. From the Citation, Wolfe saw men on board throwing their cargo into the ocean. Although Customs officers on the boats called several times for the suspect vessel to stop, it continued until the officers fired 20 rounds into its engines. The fleeing boat eventually collided with one of its pursuers. The Customs agents rounded up five suspects (wearing body armor) and took them to Cat Cay, Bahamas, where they were arrested. The following morning, an interagency task force fished out of the ocean 27 bundles of cocaine, which had an estimated street value of $11.6 million. The operation, which involved four agencies, three radar centers, five aircraft, two boats, and at least a dozen agents, should settle at least some questions about the amount of resources now devoted to fighting the supply side of the drug war.

"This one went the way we like it," Manhold says days after the arrest. "There was an end game in this case. Ninety-five out of 100 times the aircraft closes the door [after the drop] and heads south to Colombia and the boats make it to the Bahamas and the stuff eventually comes into south Florida. Sometimes we have a hard time getting our collective act together," he says.

If Manhold doesn't appear to be savoring the success, it may be because he and the other agents know the cartels are out there, changing their strategies, planning the next shipment. Miami branch chief Bill Dailey has been with the Customs Air Program since 1986. "One of the things I've learned," he says, "is that for every action, there's

a reaction. It works in physics. It works in drug smuggling too."

A recent case was based on intelligence indicating that a Cessna 182 landing at Fort Lauderdale-Hollywood International Airport might be carrying drugs. "Agents went out to inspect the airplane and found nothing," says Manhold. "They brought in a dog. Nothing. As a sort of afterthought, one of the agents noticed that the aircraft had an especially elaborate oxygen system for a single-engine aircraft. So he went back and discovered that no oxygen flowed when the system appeared to be turned on. When he examined the exceptionally large oxygen tank, he found it filled with compressed cocaine in the form of hard pellets."

Although the focus of Customs is to keep drugs out of the country, the Miami branch also engages in a sideline: going after money laundering and transporting operations, using Cessna 206s and AS 350 Astar helicopters. In communication with ground-based Customs agents who rely largely on informants, these aircraft, equipped with video cameras, carry agents aloft with hand-held gyro-stabilized binoculars. They follow vehicles they believe to be carrying profits from drug deals or cash that will eventually be delivered to drug dealers. Manhold remembers one such operation that confiscated $1.7 million in $5, $10, and $20 denominations, packaged in brick-sized bundles that nearly filled a room. Money-laundering arrests occur several times a week.

I discover quickly, however, that a lot of time is spent waiting at the Miami branch, and, like any cops hanging out at the station house, the pilots waiting in the ready room spend their time discussing theories on where the criminals are—and complaining. Some think more aircraft are getting through undetected. One Black Hawk pilot, who refused to be identified, says: "The aerostats over the Bahamas were our eyes. Now that they're down, ROTHR spends most of its time looking in the Transit Zone, and there's so much competition for the Domes that they spend very little time over here anymore. We're effectively blind."

Others believe the smugglers can spread enough money around to buy themselves a sophisticated intelligence network. Leininger says: "Some guy working on or near the airport calls them up and says 'The Dome just took off from here, so don't go out today.' There are plenty of people to give them information for enough money."

And if that's what keeps the smugglers home, so be it, says Joe Maxwell. "The General Accounting Office regularly asks why we still need airplanes if we've essentially shut down air smuggling. The answer is that if we let up they'll be back to their old ways. The proof was demonstrated in Florida early in 1998 where one of our primary detection devices was damaged for about six months. Suddenly we were having landings in the state of Florida for the first time in five or six years. In January, we seized an airplane with 880 kilos on an airstrip in a sugar cane field. They knew that radar was down."

And there will always be that kind of pressure from the air. Smuggling by air is still the most cost-effective way for the drug cartels to move their product, according to Corpus Christi branch chief Steve Jordan. "What we try to do is to make it much more expensive for them to stay in business by denying them that means of entry," he says. The Customs pilots derive great satisfaction from countering the smugglers' chess moves, and they of course take pride in their successful busts. NOWHERE TO RUN...NOWHERE TO HIDE. Maybe. But given the resourcefulness of the air smugglers, it seems likely that the bad guys will continue to figure out new ways to hide. And sometimes they do run faster.

Smugglers are wary of the Customs dragnet, so few appear these days for this Citation to track.

STRONG ARM

The space shuttle arm gave Canada a leg up in space robotics and led to a key contract for the international space station.

by Tom Harpole

When the first Canadarm, the boom that handles space shuttle payloads, showed up at Florida's Kennedy Space Center, it was an object of some consternation. From the reactions of NASA folks, the 50-foot arm might as well have been the gawky new rookie on the company volleyball team. It was 1981, and the arm showed up in Florida with a tattoo on its bicep, so to speak: a 10-inch-tall Canada logo that, to make matters worse, didn't use the austere font that NASA had chosen for the shuttle *Columbia*. And finally, in the black-and-white world of the American shuttle, the logo displayed a red Canadian flag.

"The head guy at Canada's National Research Council had told me to put the logo on the arm," remembers Bob Hayes, an engineer who helped design the arm's electrical system. "I had to find red paint that would adhere to the Beta fabric covering on the arm and not fade." When NASA officials saw the logo, they didn't see a $20 million gift from a foreign power; they saw red. "NASA told us we had to take it off," says Hayes. "We didn't budge. They said the logo wasn't in the original drawings. We told them it was a bit late in the game for all that."

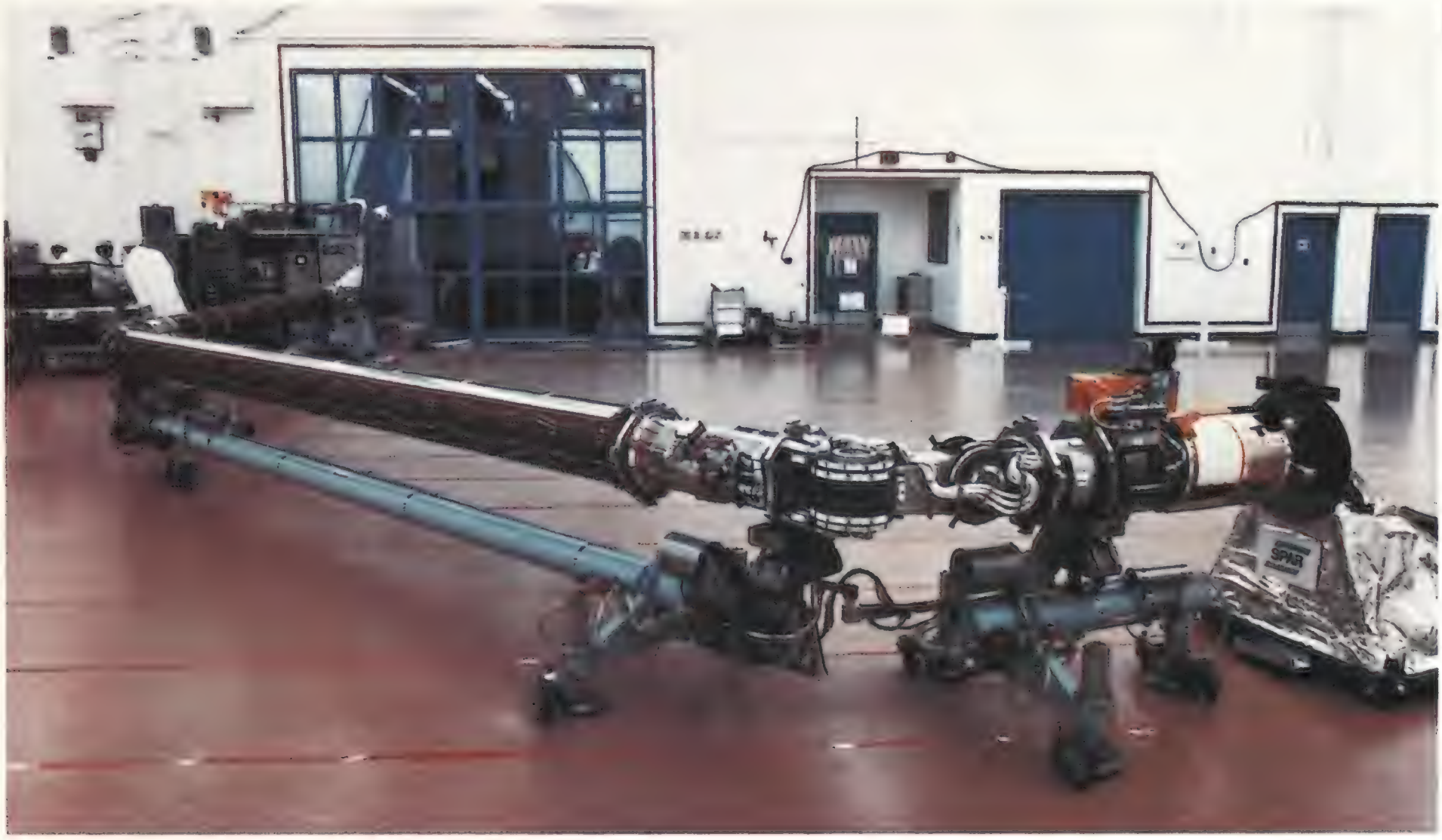
This was August. The arm was due to orbit on *Columbia*'s second flight, scheduled for November. "To their credit, some NASA guys stitched an American flag on the aft bulkhead of the cargo bay as a kind of response," Hayes continues, grinning. "Now all and sundry put their logos where the orbital cameras will see them, and I think it's a good show of national pride."

When Hayes says "all and sundry," he may be thinking of the 16 nations participating in the international space station, the orbiting construction project that got under way last December when a U.S. spacecraft was joined to a Russian one. Over the next five years, there will be opportunities for 14 other countries to show their national pride, but for sheer showmanship, it's doubtful they will rival Canada. Canada's contribution is another arm. And this one

Canada's 50-foot robotic arm has been lifting payloads into and out of the shuttle's cargo bay for 18 years.

NASA


Canada



SPAR

Each Canadarm is periodically returned to Spar for refurbishing and testing. This arm, stripped of its fabric covering, is mounted on supports, which glide along the floor on air bearings.

will be in the picture every time a new space station truss segment, module, or solar panel arrives.

Canada's arm, assisted by a Canadarm deployed from visiting space shuttles, will help assemble the space station beginning next summer. Both arms, parent and offspring, will operate as space cranes, precisely placing modules and large components, and also as cherry pickers, giving astronauts moveable platforms to work from. The new arm, however, can dance rings around the old one. It can ride on a platform that will glide up and down the station's 286-foot truss, and, more impressive, it can move independently about the station's exterior. But Canada's precocious new arm wouldn't be what it is without the robotics experience gained from building and operating the veteran Canadarm.

When NASA engineers first started thinking about the design of the shuttle back in 1969, they knew that they'd need a crane or some kind of boom for handling payloads and retrieving stranded satellites, but they didn't know exactly how they'd use the thing or what it should look like.

Enter Canada, whom NASA had invited early on to participate in the shuttle program. (Political pressures in the United States to defray the cost of the shuttle program made it attractive to involve other nations as partners. Besides saving money, international participation would make it more compromising for Congressional appropriations committees to kill the shuttle's development.) General Electric had been a leading candidate to build a remote manipulator system to handle shuttle payloads, and the company had quoted about $20 million to do it. But then Canada's National Research Council, aware that NASA would need some kind of robotic manipulator, offered to develop and build one for the first shuttle if NASA would agree to buy an arm for each additional shuttle.

"So there was some resentment in the States for our participation," says Hayes. But his colleagues drew confidence from past achievements: a role in the building of Canada's first satellite, Alouette, which studied Earth's upper atmosphere, and its successors, Alouette 2 and ISIS. Canada had aeronautical experience as well. "We could walk and talk control systems with the best of them," says Hayes. "We'd been building helicopter transmissions and gearboxes for jet engines. This was an incredibly complex new project, but we felt that we could do it."

"We" is Spar Aerospace Limited, Canada's leading aerospace company. It has grown from the Special Products and Applied Research (SPAR) division of de Havilland Aircraft of Canada Limited, which the company sold off in 1967. The main asset of the fledgling company was its 340 employees, many with IQs higher than most bowling scores.

The initial guidelines that NASA gave this talent pool were mostly constraints: The arm had to fit into a 15-inch-wide, 50-foot-long space along the port side of the shuttle's cargo bay, it had to operate on an energy budget of 1,000 watts, it could weigh no more than 1,000 pounds, it would be subjected to temperatures from –85 to +95 degrees Fahrenheit, it would have to manipulate masses from a few hundred pounds to 16 tons, and it couldn't use hydraulics (hydraulic cylinders inevitably leak oil, which would contaminate optical surfaces).

The Spar engineers all had highly evolved models for a flexible and versatile boom—their own arms. To this day you can spot a group of Spar engineers discussing the workings of the Canadarm. One person will begin point-

ing at her arm, moving it awkwardly and slowly, and others will begin imitating the cumbrous movement like people sharing tennis-elbow stories.

The remote manipulator system (NASA-speak for the Canadarm) is usually just called "the arm." It moves with the same freedom as our own. The shoulder joint, where the arm attaches to the port side of the shuttle's cargo bay, has two ranges of motion; it can pitch, like pointing up at the moon, and yaw, like swinging your arm along a horizontal plane. The elbow joint, at the end of the first 22-foot-long boom, has only pitch, as does ours. Then there's the wrist, 50 feet from the shoulder joint; it has three ranges of motion: pitch, yaw, and roll.

The shuttle arm and its descendant, the space station arm, both cinch payloads rather like a lasso. Inside their end effector "hands," cylindrical fixtures with 12-inch openings, three snare wires rotate closed like the leaves of a camera aperture. This is where the arms deviate from their human model. Fingers fumble, and so do finger-like grapples. As a grapple opens it could nudge a satellite into a spin, whether capturing or releasing it. The Spar engineers invented an end effector that could retrieve or release satellites fitted with the corresponding fixtures without bumping them into a spin.

To compare the satellite fixture to a hubcap is to incur the wrath of Spar engineers, but visually, it's a fair comparison. Picture a hubcap with a 12-inch-long shaft extending from its center. To snare the fixture, the end effector's foot-wide cylindrical mouth is guided over the shaft (see photographs, next page). This allows for a margin of error of several inches before the snare wires revolve and snap shut on the shaft. Video cameras mounted on the wrist and elbow of the shuttle arm as well as cameras in each corner of the cargo bay aid the operator in getting the end effector over the shaft. Finally, a video camera mounted on top of the end effector focuses on a cross-hair target on the fixture's hubcap-like plate. As the end effector closes in, the arm's operator looks to see how matching crosshairs on a video screen are aligning with those on the target. Once the snare wires snap shut, the end effector draws the shaft further into its maw.

KATHRYN GAITENS/LIAISON AGENCY

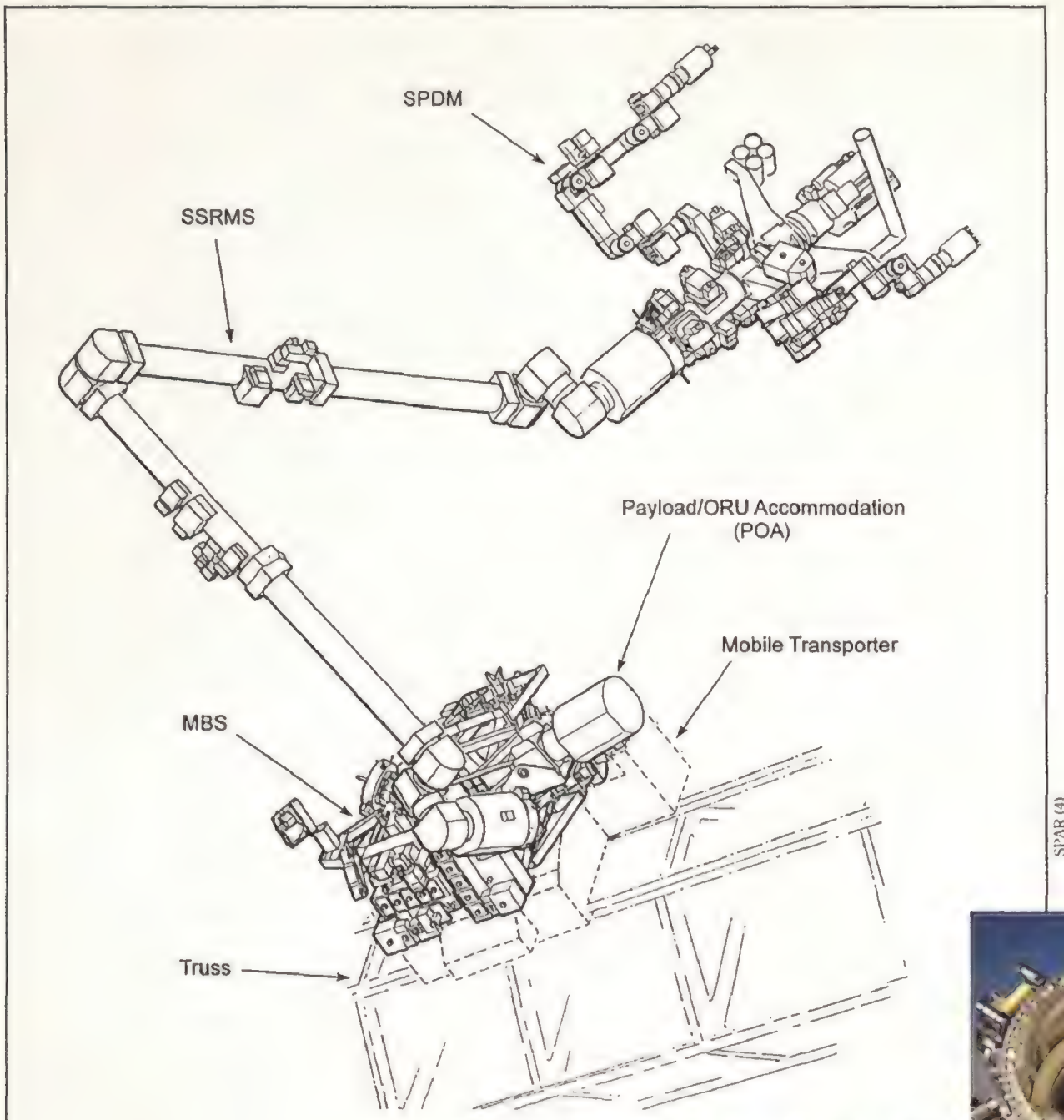
The engineers working on the space station arm are a multi-generational crew: (left to right) Ron Taplin and Bob Hayes, who worked on the shuttle arm, have joined forces with John Lymer and Aaron Hoag in getting the station arm ready for launch next summer.

The space station's attachment fixtures (NASA prefers the wordier "power-data grapple fixture") will differ somewhat from those affixed to satellites snared by the shuttle arm. For starters, they'll have a power and data port to provide the arm with electricity and allow signals to flow between the arm and its human operator, who will work out of the space station's cupola module. Since the space station arm will have to manipulate masses with an inertia equivalent to 250,000 pounds, its end effectors—in addition to the three snare wires—are each fitted with four latches that can lock into four corresponding pockets on the hubcap-like plate of the station's power-data grapple fixtures.

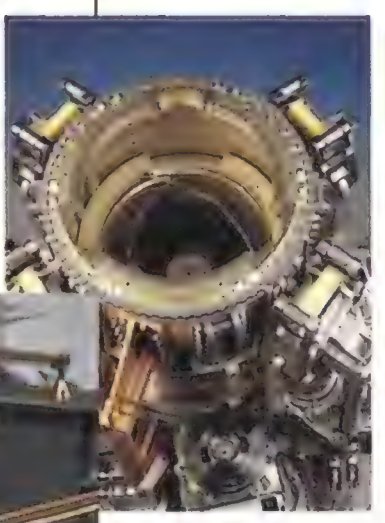
The trait that distinguishes the shuttle and space station arms from other human-operated machines, such as a backhoe, is the computer programming that makes their movements possible. The astronauts who have operated the Canadarm call it "flying the arm," because the experience of manipulating objects with it is more like flying an aircraft than pulling levers to dig a ditch. The astronauts first start getting the feel of the shuttle and space station arms in computer simulators that, at least in the case of the Canadarm, are praised by astronauts as very realistic simulations. "What you get in space is what you saw on the simulator," says Chris Hadfield, the first Canadian to operate the shuttle arm. "We assume that the simulations for the space station arm are similarly analogous to how it will feel, but you don't know exactly until the station arm flies."

The controls, which are set up similarly for both arms, are twofold. There is a control for the right hand that looks and feels like the joystick in a fighter jet; it controls rotational movement—pitch, roll, and yaw. The left-hand control, which looks like a square doorknob, initiates translational movement: up, down, left, right, forward, and backward. Each time the controls are moved by a human operator, tiny electric currents are generated, which an arm computer translates into the desired movement at the end effector.

Think of putting your finger at a point on a map. Your fingertip is your point of resolution, or POR, as the astronauts say. To get your fingertip on the map, you don't have to tell your shoulder, elbow, and wrist how to move to get it there. Or say you want to draw on the map. Your POR is now the tip of a pen, and likewise, you don't have to tell each finger its role in holding the pen or tell your joints what to do to track the pen across the map. The arms' computers allow them to function almost as inde-



SPAR (4)



The space station arm can anchor itself to a mobile transporter, or sled, that rides along the station's 286-foot truss (above). Attached to the arm's other end effector is the special-purpose dexterous manipulator, a two-arm robot designed to perform tasks requiring delicacy, like replacing electronics. The close-up at the far right shows two of the end effector's steel snare wires, which close tight around the shaft extending from the center of a grapple fixture (right). Aiding the arm's human operator in guiding the end effector over the grapple fixture is a black-and-white cross-hair target, which is viewed by a video camera on top of the end effector.

pendently as a human arm; thousands of lines of code enable them to coordinate the movement of the robotic joints, allowing the astronaut to focus on the POR. Another robotic feature of the shuttle and station arms is their ability to monitor their own health and to notify the operator if something is awry. The arms can also be moved joint by joint if necessary, and they can be programmed to maneuver without the input of a human operator for routine tasks, freeing astronauts from constant hands-on input and monitoring.

When working in concert, the six motors that run the various joints of the Canadarm consume a total of less than 300 watts of electricity. That means the arm can move the equivalent of a rail car loaded with grain using about the same wattage as a hand-held electric drill. It does so with gear ratios of 1,800 to 1 in the shoulder, 1,250 to 1 in the elbow, and 325 to 1 in the wrist. The rest of the electricity is consumed by electric blanket-like heaters that protect the arm's joints from the cold of space by warming them to about room temperature under the Beta fabric, which is made of Teflon-reinforced glass cloth.

Nancy Currie, who flew on shuttle mission STS-88 last December, assembled the first two pieces of the space station with the Canadarm. The Russian-built Zarya and U.S.-built Unity modules each have masses of more than 12 tons. Though weightless in space, had their masses collided, the damage could have been catastrophic. "What the arm does with masses in microgravity is to accelerate them and decelerate them," explains Currie. "You want to move them as slowly as the arm will fly, which is about one-tenth of a foot per second."

When Currie describes how she manipulated the massive space station modules, she doesn't pantomime as though her hands are on the controls; she moves her arm in the space in front of her, as though her arm is the arm. Flying the arm is more intuitive than mechanical, she explains. Then, while moving her right arm slowly, robotically, she reviews, in the first person plural, how she put the first two pieces of the space station together: "The Unity module was stored in the cargo bay. There was an inch of clearance on each side of it as we lifted it into a vertical position above the cargo bay. Then we lowered it to a position in the forward bay right in front of us, where it was suspended about four inches above the shuttle's docking apparatus." The arm was not designed to exert force, so a pulse of the shuttle's thrusters drove the orbiter up into the Unity module to complete the docking.

The Russian Zarya module, which was to be stacked on top of the Unity, was in orbit about 1,000 miles away. The

next day mission commander Robert Cabana pulled the shuttle to within about 15 feet underneath Zarya. Currie's vision was completely blocked by the three-story Unity sitting right in front of the shuttle's windows. Cameras on the arm's wrist and elbow and in the two aft corners of the cargo bay provided her only view of Zarya. She captured the module and manipulated it to a position a few inches above the docking port on the Unity so that the thrusters could complete the docking.

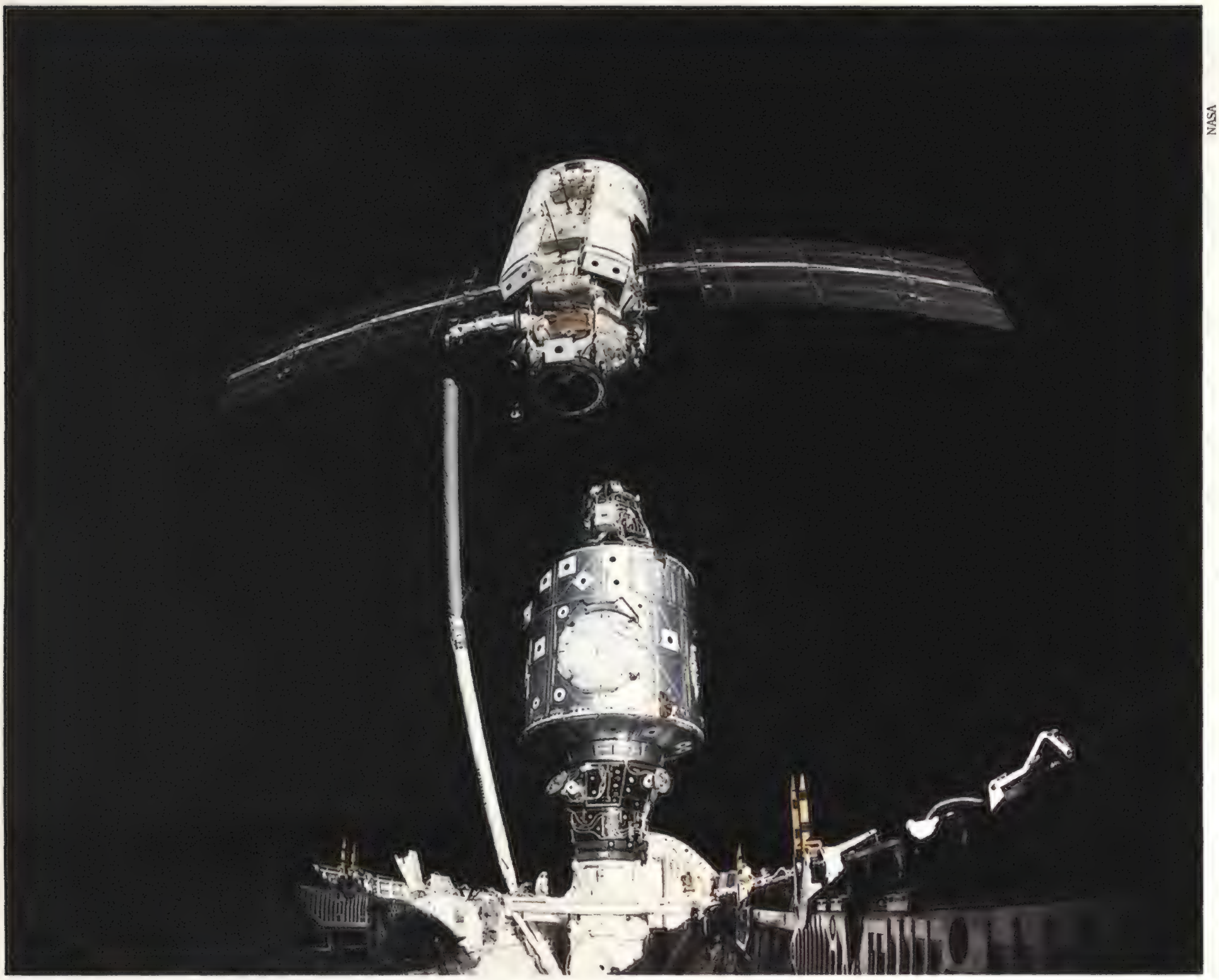
Currie's performance came off so flawlessly in part because of some exquisite engineering that limits oscillations in the arm. Ron Taplin, a charter member of Spar's Canadarm project, explains that robots need a balance of precision and flexibility. "There is a certain amount of flexibility designed into the arm, mostly that which occurs in the carbon-graphite boom sections between the joints," he says. "Flexibility is good, jerkiness isn't. Robots jerk because of sloppy tolerances in their gear teeth and bearings."

DAVID NANCE

Training at the Johnson Space Center in Houston, Texas, astronaut Chris Hadfield (right) checks out the Canadarm's cylindrical end effector, poised above a full-scale mockup of the shuttle cargo bay. Spar's Mike Hiltz uses computer simulation to determine the safest and most elegant sequence of arm movements for the assembly of the space station.

Getting a mass moving was just half of the design challenge for the Canadarm engineers. Decelerating the inertia requires driving the electric motors backward, effectively turning them into little generators. The transition, however, between acceleration and deceleration must be so smooth that the arm operator shouldn't see it happening. Any slack in the arm's gears and bearings would translate into unacceptable lurching and bouncing. So Spar engineers had to spend two years researching dry lubricants that wouldn't ball up in the infinitesimal space between gear teeth and bearings.

Taplin explains all of this in Spar's clean room, where the Canadarms and the space station's remote manipulator system are assembled and maintained. It is a room no bigger than a high school gym. The original Canadarm is home for a refurbishing, and its offspring, the station arm, is in its last stages of assembly. Both arms evoke images of multiple-trauma victims, lying blanketed and cradled at every joint. Attendants wearing hairnets work as quietly as nurses. The floor is a pale green slick epoxy so precisely leveled that a dropped ball bearing bounces straight up and down until it comes to rest without rolling. Since the shuttle arm can't support its own weight in Earth's gravity, it is mounted on supports, which float along the floor on air bearings. The cushion generated by the air bearings allows technicians to test the arm's articulation. But this method makes possible the testing of only two ranges of motion; then the arm must be rotated 90 degrees and



NASA

Last December, a shuttle arm grabbed the Russian-built Zarya module (top) and guided it to a docking with the U.S.-built Unity module, forming the infant space station.

tested for the third range of motion.

The station arm's joints can all be manipulated and tested independently in the clean room, but no one will know how effectively the whole thing will work until it is assembled and tested in space. "If the computer simulations that Spar has created for the station arm are of the same quality and fidelity as the shuttle arms, the astronauts are getting a good feel for how the station arm will work," says Taplin.

Although the station arm descended directly from the Canadarm and looks similar, there are a few significant differences. It won't be brought home for repairs, so all of the joints, motors, boom segments, and end effectors are removable. The station arm weighs 3,200 pounds compared to the Canadarm's 905 pounds, and it is eight feet longer. The station arm's most notable design departure, however, is its symmetry. Instead of a fixed shoulder joint, it has wrists and end effectors at both ends. It will be able to step off of the mobile transporter and move around on the space station from one power-data grapple fixture to the next. Think of a Slinky working its way down a flight of stairs. Or imagine reaching back over your shoulder and grabbing a point behind your back. Then detach your arm at the shoulder, which now becomes a wrist and hand that reaches for the next grapple fixture.

In addition to the 18 modules and the truss system, the space station will have more than an acre of solar arrays and, oriented toward deep space, a series of radiators that stand three stories tall when the station is fully assembled in 2004. The space station arm will have to move around this maze like a gymnast doing handsprings through a parking lot full of cars.

Overhead at Spar's clean room, buzzing metal halide lights are too bright to look into, yielding a light excellent for examining mechanical parts but not very flattering to human complexions. Under the stark light and billowing white hairnets, liver spots and pimples vividly delineate the various generations of engineers working at Spar.

But preferences for working with either imperial weights and measures or the metric system are more to the point. John Lymer, a 37-year-old engineer, has spent most of his life since his university days working for Spar, and he works with the imperial system that he used

in his studies. His 24-year-old colleague, Aaron Hoag, works only in metric. "We don't speak to each other without a conversion table in hand," laughs Hoag. Says Lymer: "All the specifications we work with have to be in metric and imperial, and this probably won't change until the United States finally switches over."

Lymer, chief designer, and Hoag, his heir apparent, are working on the special-purpose dexterous manipulator—"Dexter"—a robot that replicates the human torso and arms. Dexter's 11-foot arms have a total of 14 joints. The robot will be mounted on the end of the space station arm as needed, saving the astronauts from performing extravehicular activities for such simple tasks as changing circuit breakers and batteries. Dexter, riding the space station arm's end effector, will be the human operator's first point of resolution; the secondary POR will be Dexter's "hands," or end effectors.

Rather than using end effectors fitted with snares, as the shuttle and space station arms do, Dexter's two end effectors have jaws that close with Rottweiler force on either three-inch or one-and-a-half-inch titanium cubes mounted on all of the space station's external objects that will need to be periodically replaced. The operator, watching images from the robot's waist- and arm-level cameras, will try to align crosshairs on the video screen and target. Slopes cut into the center of the titanium cubes guide Dexter's grippers (two grippers on each end effector) to a positive connection, and once the object is firmly grasped, a 7/16-inch socket inside each gripper will envelop a corresponding nut on the object being removed by Dexter.

"Every fastener on the space station that interfaces with either Dexter or an astronaut on an EVA [extravehicular activity], whether built by the U.S. or any other of the 16 contributing countries, has to be an imperial system 7/16-inch nut," Lymer says with a chuckle.

"That translates into exactly 10.5 millimeters," Hoag adds cheerfully.

"Hardly a standard socket size," says a triumphant Lymer.

With the space station having a projected useful life of 30 years, it's quite possible that the last place where imperial fasteners are still used won't be on Earth.

Off in a corner of the Spar clean room reside the mobile transporter and the mobile base system, which make up the foundation of the station's remote manipulator system. The mobile transporter is designed to travel along the space station's 286-foot truss on wheels that grip rails top and bottom. The mobile base system acts as a foundation for the station arm, as well as a parking place and working platform for Dexter and a storage area for tools and replacement parts.

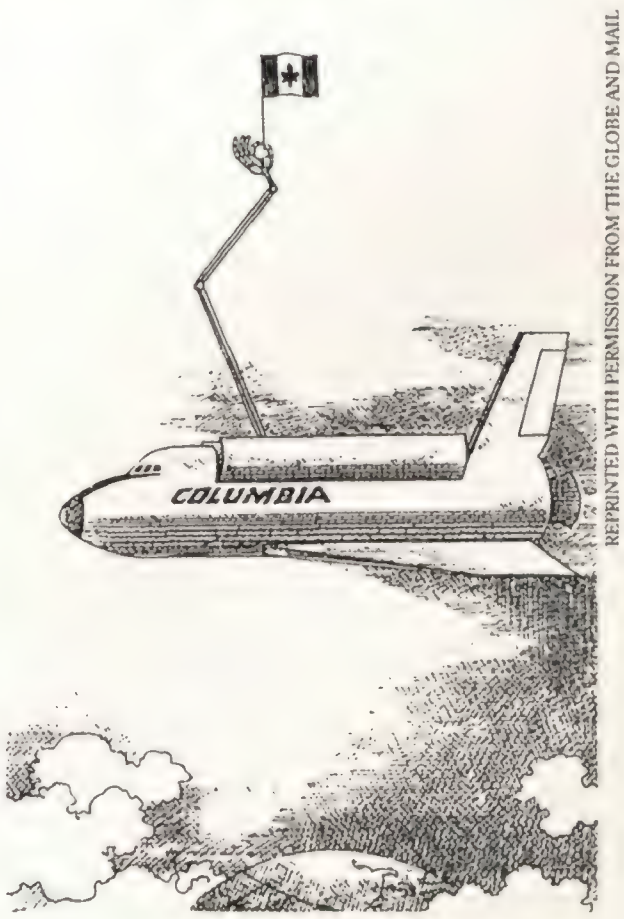
Last April the space station arm was rolled out of Spar headquarters near Toronto and taken to the Kennedy Space Center in custom-built containers loaded on four semi-trailers. One of the most valuable shipments ever transported by truck, it had a police escort along the entire 1,400-mile journey. At every state line, troopers handed off the convoy to the next state's highway patrol.

The next big handoff will be sometime in late summer of 2000, when Canadian astronaut Chris Hadfield, operating the shuttle arm, and Jim Voss, operating the space station arm from the cupola module, will hand back to the shuttle the pallet that the space station arm arrived on. "The pallet has decent mass. It will be a good test," says Hadfield. Voss will pick up the pallet, slowly move it away from the space station, and swing it toward the shuttle. Then Hadfield will take hold of it just as Voss lets the space station arm go limp so that the two arms don't strain against each other. The maneuver will be the first time that two arms built in Canada work together on space station construction. A rapt audience of engineers in several countries will be watching the live broadcast.

Bob Hayes won't be in the Johnson Space Center mission evaluation room as he was in 1981, when the tattooed Canadarm made its maiden voyage. "Everyone in that room stood and faced the Canadians and applauded for several minutes. I had a huge lump in my throat," says Hayes, with a lump in his throat. "When that first maneuver happens between two arms, I'll be riveted to a TV. Imagine the scene, two flexible members making a handoff in space. Under the arc they form, the arc of the Earth." Hayes pauses, then says: "We have come a long way from knowing nothing about doing this 30 years ago."

Eighteen years ago the original arm was to have been attached to *Columbia*'s cargo bay for missions only when its use was planned. Now Canadarms are a permanent fixture on all four shuttles. Plans call for using the space station arm at least 80 times during its first year on the job, but it will probably prove unexpectedly useful as well. Chris Hadfield likes to point out that the Canadarm has been used as a work platform for astronauts on EVAs, for inspecting the shuttle's tiles and other fragile external parts, and for moving IMAX cameras (another Canadian invention, he points out) around to shoot footage for large-format movies. The shuttle arm has also nudged solar arrays into alignment. It's even served as an icepick and a sunshade. None of those jobs were anticipated in the original documents for the shuttle arm, the same body of paperwork that didn't include the Canada logo. But the arm has earned respect and promoted international flexibility.

"Every time a shuttle returns, it is refurbished and a little Canada sticker on the Canadarm control panel gets scraped off because it wasn't in the original drawings," says Hadfield. "But now someone at Kennedy puts a fresh one on before every flight."



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For Jimmy Doolittle and sons (below) and B.J. London and girls (right), flying was a family affair, as it was for the great-grandfathers of flight, the Montgolfier brothers.

COURTESY BARBARA LONDON

NASM

PHOTO TREATMENT BY DAVID POVILAITIS

NASM (2)

The FLY Chromosome

In some families, a pilot's license is as predetermined as eye color.

by Reina Pennington

It all started with two brothers. Not *those* two. Back in 1783, the Montgolfier boys—Joseph and his kid brother Etienne—sent two Frenchmen skyward in a hot-air balloon and started a tradition taken up over the next two centuries by hundreds of families. The Wright brothers are merely the best known in a category that includes Baron von Richthofen, whose brother, Lothar, shot down 20 enemy planes in a single month of World War I; the Shorts brothers—Eustace, Oswald, and Horace—who established the first aircraft factory in Great Britain; the Stinson sisters, Katherine and Marjorie, flight instructors in the Wright B trainer whose brothers followed in *their* footsteps; and General Jimmy Doolittle, whose piloting skills were so strong that he passed them along to both son and grandson.

In fact, the Famous Families of Flight category is so large that it prompts the question: Is there a flying gene? What do people mean exactly when they describe a flier as "a natural pilot"? I canvassed a few of the families flying today to find out whether the love of flying is simply "catching" or something deeper down, a part of a person's makeup, carried in the blood.

The Fabulous Flying Dishart Brothers

You've seen Gregory Dishart fly. A former instructor at the Naval Fighter Weapons School, formerly in California, he flew the F-5 that, playing the role of a Soviet MiG, gave a pilot playing the role of Tom Cruise a run for his money in the movie *Top Gun*. Greg is the middle son of Urban and Theresa Dishart of Pittsburgh, Pennsylvania, and just one of four pilots in a family with five sons. Oldest son Urban III started it off in the early 1970s, eventually serving as an F-16 squadron commander at Moody Air Force Base in Georgia. Second-born Danny flew the A-6 as a Marine, one of the few Marines to become a landing signal officer on a

COURTESY PATTY WAGSTAFF (2)

COURTESY ANDREA TART

COURTESY THERESA DISHART

Left to right: Aerobatic champ Patty Wagstaff, her airline captain sister Toni, and former Air Force pilot Andi Tart all "inherited" flying from Dad. Below: Four out of five Dishart brothers recommend flying careers.

carrier, and Jeff joined the Air Force—the only one in his class at Oklahoma's Vance Air Force Base to be assigned the F-16 fighter. Jeff earned his own 15 minutes of fame during a brief tour as a tanker pilot in the Air National Guard when he refueled Captain Scott O'Grady minutes before that fighter pilot was shot down over Bosnia; he later refueled the rescuers. The air services don't keep detailed records of relatives who fly, but my informal survey suggests that the Disharts are very likely the only four brothers ever to fly military jets at the same time.

Jeff claims the whole flying thing was his idea: "It wasn't a case of them infecting me with the flying bug. Urb wanted to be a gangster, Danny a doctor, Greg a vet. I wanted to be a pilot. It was always frustrating for me later when people said, 'You're following in your brothers' footsteps!' "

The sons caught the bug from their dad. Even with no formal background in aviation, Urban II, an ex-Marine who became a chemical engineer, loved airplanes. The boys grew up with airplanes decorating their bedrooms. Dad built and flew gas-powered model airplanes with them; he paid for them to take rides in real airplanes. Growing up in the 1960s, son Urb recalls, "We didn't have a lot of money, so we used to go out to the Pittsburgh airport. A big jug of Kool-Aid and five little Dishart boys, watching airplanes take off and land. That was fun, for us."

Greg remembers getting an aircraft carrier as a toy, "one of those metal ones with the folding wings on the airplanes. The Navy always had an appeal to me." He was a soft touch for the Navy recruiters at a table in the student union. Urb had also started in college. "The thing that got me into it, really, was the necessity of paying for school," he says. An ROTC scholarship got him the money, and a shot at a pilot slot.

The Dishart boys didn't set out to create a fighter pilot dynasty. "It was never one of these 'One for all and all for one, let's do this together,' " says Greg. Urb adds, "We were all so busy getting through school and training, it didn't really hit me that we were all doing this until the ball was rolling pretty good. We were always very close, always seemed to do well in the same things. I did well as a fighter, so it didn't surprise me that the others also got fighters. That's what we do."

Well, mostly. Youngest brother Steve has kept his feet on the ground, now serving as vice president and director of communications for Mellon Bank. Though he says he felt like "chopped liver" on occasion when the newspapers kept interviewing only the flying Dishart brothers, Steve adds, "I didn't feel an outcast. We all chose freely what we wanted to do, and we all supported each other."

The pilots have now abandoned their fighter jets, but they can't stay earthbound: Urb and Jeff are flying for United Airlines, Danny for US Airways, and Greg for Delta.

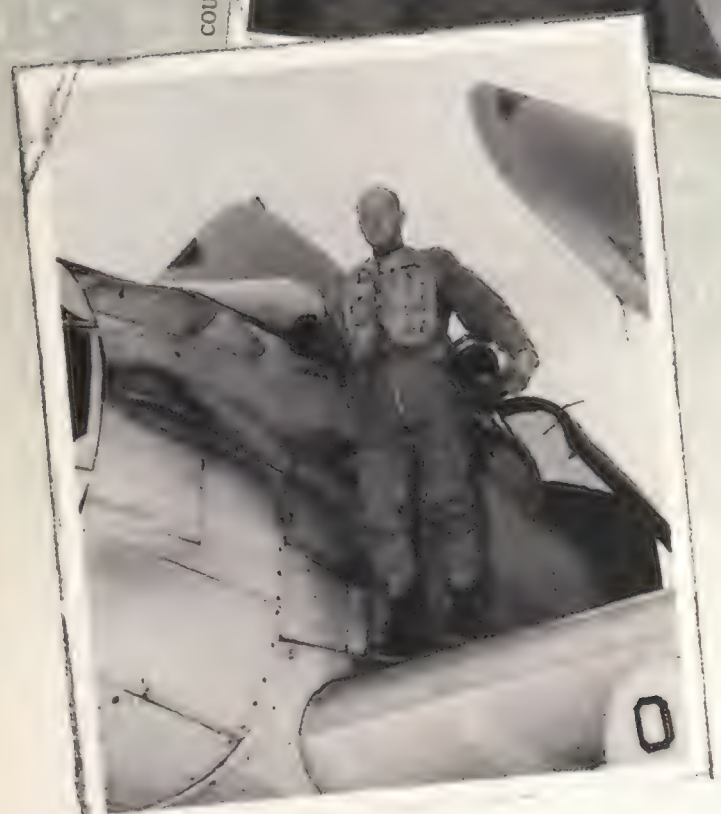
Dad finally fell in line. "He eventually got his license, after we were all in the military," says Urb. Urban II died in 1996. "He was a damn good aviator," says his oldest son. "I thought he was a natural."

Sisters in Flight

Eddie Stinson was the first pilot to demonstrate spin recovery, but not the first in his family to fly. His sisters Katherine and Marjorie both beat him into the air. Once there, the two women developed completely different flying personalities. Marjorie was known as "the Flying Schoolmarm." Her main interest was the flight school she ran with her sister, where they trained Canadians for the British air service. Katherine, on the other hand, was a performer. In 1915 she flew 80 consecutive loops and performed in Tokyo for an audience of more than 25,000.

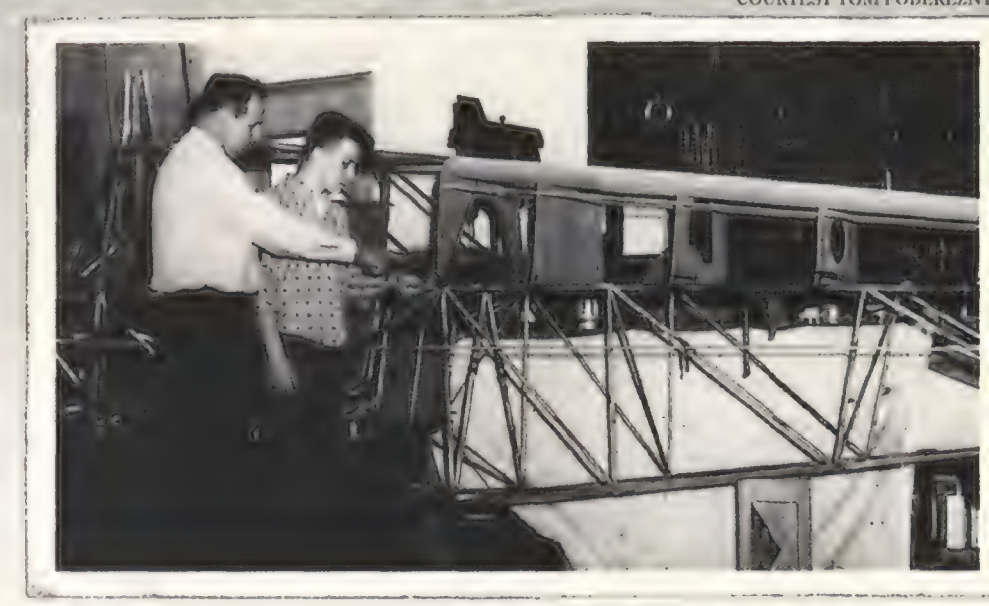
Fast-forward a couple of generations: The Combs sisters are also both pilots, but they too have taken different routes

COURTESY PETERSEN FAMILY (2)



Amy Petersen met husband Craig (a Navy pilot's son) on the first day of Navy flight school. Guess what childhood pastime Tom Poberezny shared with his father?

COURTESY TOM POBEREZNY



into the sky. Toni wanted to fly from an early age. Her father was a pilot as long as she can remember, having followed an Air Force tour with a 24-year career with Japan Airlines. Toni is now a 757 pilot for Continental Airlines.

Patty took a more circuitous route, drifting around the world, living on a sailboat in ports from California to Australia, waitressing in Alaska. You probably know Patty by her married name, Wagstaff, and as a three-time U.S. National Aerobatic Champion. As Toni puts it, "She and I have the yin and yang of piloting careers. Patty gets paid to fly upside down and I get paid to keep it right side up."

Their dad certainly influenced both girls' choices; flying was a bond among them. "It probably made my father and I closer," says Patty. "When I grew up, dads didn't do much with the kids. However, when I was a kid I flew with him. He'd always let me sit in the cockpit and fly the plane, up in the seat. We had a difficult relationship. But I think the best times we ever shared were definitely in the cockpit. And now it's still really the only thing we have in common."

Patty, taking a page from the barnstorming Stinsons, is more competitive than the other pilots in the family. She says, "When I started, women pilots really were just competing against the other women. I'm here to beat the men too."

Like the Stinsons, whose mother helped purchase their flight school, many of today's fliers got started because of Mom. B.J. London runs an aircraft company in Long Beach, California, and began flying back in the 1940s, when she was one of the original 25 women accepted into the Women's Auxiliary Ferrying Squadron. Her two daughters fly—one was the first woman hired by Western Airlines, and is now a captain with Delta. "We never went to grandma's in a car, we always flew," says London. "From the time the girls were in a basket, they were always in the back of an airplane."

Look at the family trees of any number of contemporary pilots and you almost always find more than one set of wings. There's airshow performer and Experimental Aircraft Association president Tom Poberezny, whose father, Paul, founded the association. Or Andi Tart, who decided at age nine, when her Navy veteran father took her to her flying lessons, to go to the Air Force Academy. Craig Petersen, former Navy A-6 pilot, is the son of a former Navy pilot—and the husband of a former Navy pilot who now flies for United Airlines. He says, "I think our little boy was almost four years old before he finally realized that everyone's mommy didn't fly airplanes." Burt Rutan developed the unique Voyager aircraft, and his brother Dick copiloted it on the first unrefueled circumnavigation of the globe. Or the Fellowes brothers, all three naval aviators: Jack ended up as a prisoner of war in Vietnam, away from his son John for seven years. And still, John wanted to fly just like his dad (even had his name misspelled on his A-6 like the old man's was on his).

Lindy's Legacy: Nature or Nurture?

The anecdotes from the families all point to the "at the knee" education that was hard to resist. So other forces besides heredity may have been at work.

"I'm not sure it was possible to *catch* the [flying] bug, because the bug had you surrounded," says Tom Poberezny. "My dad started the EAA in '53, and after that it was aviation 24 hours a day in our family, whether it was building airplanes in the garage or going out to the airport. My dad ate, slept, and dreamed airplanes."

Toni Combs, however, gives a nod to genetics. "At least in my family, flying definitely runs in the blood," she says. "For all of us, flying is a passion, and every time we get to go up we have

COURTESY FELLOWES FAMILY

John Fellowes—Jr. and Sr.—flew Navy A-6 Intruders (left). The senior Fellowes was one of three naval aviator brothers. Mathilde Moisant (right) had a barnstorming brother who got her into the act.

NASM

smiles on our faces." Sister Patty agrees. "The genetic part is things like good eyesight, and tending to little details while keeping the big picture in sight. We were born with a certain set of skills that happened to be good for flying." Others refer to the competitiveness of flying (especially fighters), the hand-eye coordination, spatial orientation, something physiological. Or an attitude, says Jeff Dishart, a "zest for life."

Still, if there is a gene, it could be recessive. Consider our most famous aviator, Charles Lindbergh. Flying was his life, and he shared the passion with his wife, Anne Morrow Lindbergh. He took his five children flying, and not one of them chose aviation as a career.

But he did teach them to fly. "I think it was a way of exposing us to a world he loved himself," says daughter Reeve Lindbergh Tripp. "But we were actively discouraged from flying as a profession," she adds. "My father loved flying in the old days, but I think his sense was that the fun was over."

Keep on looking down the family line and you will find that irrepressible urge playing itself out. Lindy's sons Scott and Jon flew small aircraft and ultralights, and Reeve herself set her sights on a private license until a riding accident made it impossible. Jon's son Erik worked as a flight instructor until he was grounded by rheumatoid arthritis.

Erik wasn't encouraged one way or the other to fly. "For me, growing up on the West Coast, removed from most of the historical aspects of flying in my family, I didn't think about it," he says. When he finally did decide, in college, he kept his family connections secret. He recalls, "When I took my Certified Flight Instructor check ride, I did fine. When we got back we were sitting in the plane, and the instructor was writing up my new ticket, and he asked me how to spell my name. And he said, 'Any relation to Charles Lindbergh?' And I said, 'Yes, he's my grandfather.' And he said, 'Well, you should've told me that before we flew! You wouldn't have even had to fly!' And I said, 'That's why I didn't tell you.' "

Erik hopes to become the first Lindbergh to fly in space. He is now promoting the X-Prize, a $10 million purse that will be awarded to the first privately funded suborbital space launch. Lindbergh also hopes to be one of the first passenger-astronauts.

Lindbergh's descendants may not have made aviation their vocation, but a love of flying is part of the family legacy. Reeve Lindbergh Tripp predicts, "I expect there will always be Lindberghs who are pilots."

And likely Disharts and Wagstaffs and Stinsons. While I was talking to Andi Tart, one of her five-year-old twins tried to answer my questions. Andi told her, "You're not a pilot!" The little girl answered, "Not yet!"

Still not convinced? Think back on those times when you got the urge to fly. Do you suppose you were the first in your family to feel that way? You might have something in common with the generations of sons, fathers, sisters, and brothers who have followed each other into the sky:

• **Mathilde Moisant**, one of the first women to earn a pilot's license, was inspired by the first barnstormer: her brother John.

• **Edwin Link**, inventor of the famed Link trainer, first used the simulator to teach his brother to fly.

• **Henri Farman** flew solo in 1906 to make the first publicly monitored circular flight of one kilometer. But he later built his aircraft factory and airline in partnership with his pilot brother Maurice.

• **Laurent and Louis Seguin** (cousins of the Montgolfiers) developed the Gnôme rotary engine.

• **Léon and Robert Morane**, as well as **Edouard and Charles Nieuport**, developed monoplanes for the French before World War I.

• **Reimar and Walter Horten** built gliders and Luftwaffe aircraft in World War II and designed the first flying wing.

• **Paul Tibbets** was a member of the 509th Composite Group when he piloted the B-29 *Enola Gay* on that 1945 mission to Hiroshima. Today that unit is the 509th Bomb Squadron, and one of its pilots flying B-2 Spirit strategic bombers out of Whiteman Air Force Base in Missouri, is Paul Tibbets IV, Paul's grandson.

• **Mark and Scott Kelly** have together made over 625 carrier landings in F-14s, F/A-18s, and A-6s. They were both selected as astronauts in April 1996 and are currently qualified for flight assignments. They'd be perfect for a new Gemini mission: The Kellys are NASA's first twins.

Almost 70 years after two aerial explorers discovered a remote region of Peru, scientists are returning to investigate the

SECRETS of the Colca Valley

by Frederick Engle

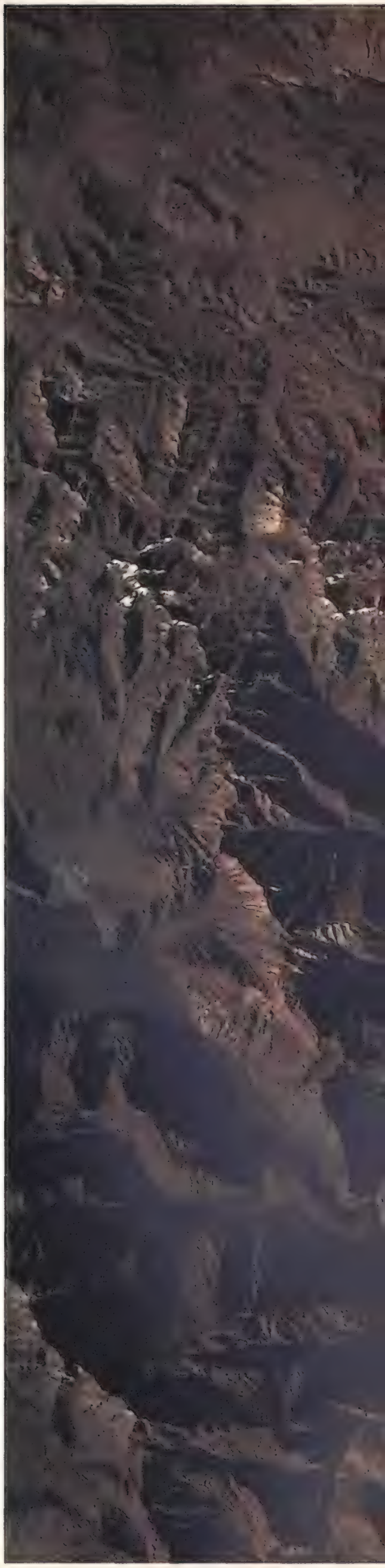
In 1991, a colleague at the National Air and Space Museum and I began putting together a book of photographs to be titled *Looking at Earth*. The project required us to spend many hours searching for images. One day, as I was scrolling through rolls of film taken by astronauts on a 1988 space shuttle mission, I came upon a photo of snow-covered volcanoes, dark lava flows, and a deep canyon. I recognized the site as the Rio Colca Valley in Peru, a fascinating place I had traveled to six years earlier as a geography graduate student investigating damage from the 1982-83 El Niño event. Looking at the photo, I recalled a mountainous landscape and remote villages where the residents raised alpacas for wool and grew potatoes, maize, and other subsistence crops.

That shuttle photograph started me on a journey back to the Colca.

In 1997, I set off with two colleagues, Mark Bulmer and Andrew Johnston of the National Air and Space Museum's Center for Earth and Planetary Studies. We wanted to investigate reports that a volcano named Sabancaya had erupted in 1991. And we wanted to see if the region would be suitable for a natural hazards study, one using the products of remote sensing technology—shuttle photographs and satellite images—as well as fieldwork. Such a project would be useful to the communities threatened by eruptions, earthquakes, and other hazards. And finally, we wanted to see how the geography of the valley was changing over time.

For the latter, we were fortunate to have with us photographs taken by another team that had fallen under the Colca Valley's spell, more than 60 years earlier.

In the late 1920s, a photographer and pilot named George Johnson with the U.S. Naval Reserve spent two years detailed to the Peruvian Naval Air Service making aerial surveys of that country's coast. On one mission in the south,



This shuttle-eye view would hold no significance to most people, but in it the author recognized a little-known valley in Peru he'd once visited. In 1997 he and his colleagues returned, this time to check out reports that a volcano named Sabancaya (circled) had erupted.

NASA

NEG. #BB273/COURTESY AMERICAN MUSEUM OF NATURAL HISTORY

Johnson took a photograph of a deep valley that breached a chain of 20,000-foot volcanoes. Within the valley were 14 villages, each of which was laid out along a gridiron pattern. Etched into the valley's steep walls were broad steps, or terraces, which the valley residents used as plots for raising crops.

When Johnson returned to the States in 1930, he showed his photographs to officials at the American Geographical Society. The geographers there, keen to promote aerial photography, published his work in a 159-page book entitled *Peru from the Air*. The organization also resolved to send him back to South America for a full-up expedition, including aircraft, to photograph more of Peru—especially the "lost valley" he had captured so dramatically. For geographers, that complex landscape was like an old manuscript waiting to be read.

The Colca was part of a region that the Spanish Empire had ruled from the 1530s to 1821. During this period, the Spanish had moved the native settlements down from the mountains onto plateaus and had reorganized their layouts into grids, in accordance with plans developed by the Council of the Indies, Spain's main body for administering its colonies. (The valley's agricultural infrastructure—the terraces and irrigation canals—had been established before the Spanish conquest.) After the collapse of the empire in the Americas, the valley became increasingly isolated. By the time Johnson spotted the Colca, the villagers had almost no contact with the outside world, except for once each year when they would lead pack trains of llamas carrying alpaca wool to the city of Arequipa, 70 miles beyond the valley.

COURTESY AMERICAN GEOGRAPHICAL SOCIETY

Though the 1931 team focused on the Colca Valley, they investigated other parts of Peru, including a northern region (above, inset) where they discovered the pre-Incan Great Wall, and the Atacama desert in the south, where Robert Shippee and George Johnson landed near a dune (top).

As usual with expeditions, funding was a problem. But Johnson had become acquainted with a young pilot, Robert Shippee, at the Red Bank New Jersey Aero Club. Shippee had studied geology while at Harvard, and he was also interested in promoting aerial photography. He persuaded his father, a stock broker, to underwrite the project.

In November 1930 the Shippee-Johnson Peruvian Expedition purchased two Bellanca Pacemakers. At Bolling Field in Washington, D.C., the Peruvian ambassador's wife christened the Pacemakers the *Washington* and the *Lima*. The aircraft were painted the easy-to-spot international orange, and their 300-horsepower Wright Whirlwind engines were supercharged for high-altitude flight (they would be flying at 8,000 to 24,000 feet above sea level). The *Lima* would serve as the team's transport vehicle, while the *Washington*, equipped with oxygen for the pilot and the photographer, would be the photographic aircraft. The expedition's photography equipment included a large-format Fairchild K-6 for taking oblique-angle photos through an open window in the aircraft's side, and a large-format K-3 camera mounted in a bay in the aircraft's belly for vertical photos.

Shippee and Johnson assembled their team in New York: chief pilot Irving Hay, civil engineer Valentine Van Keu-

ran, and mechanic Max Distel. On December 6, 1930, the team sailed on the Grace Line steamship *Santa Maria*. Two weeks later they arrived in Peru.

The expedition uncrated and assembled the Bellancas at an airfield in Lima. The *West Coast Leader*, Peru's English-language newspaper, announced the arrival with an article reporting that the expedition planned to "offer valuable aid to science and a better knowledge of Peru" by "taking aerial views...to be utilized in institutions and by men of science."

In late January the expedition flew north to investigate ruins along the coast. The team surveyed Chan Chan, an 11-square-mile complex of adobe palaces, temples, and walls that served as the center of the great pre-Incan Chimu empire, which dominated coastal Peru around 1300 AD. Johnson, using skills learned as an observer in the Great War, produced a photo-mosaic map of Chan Chan. He had the *Washington* flown on a steady course and at a constant altitude in repeated passes over the entire site while the vertically mounted camera took photographs at regular intervals.

In the north the expedition made one sensational discovery, something no archaeologist had ever observed. During one flight, Johnson observed a wall running from the coastal Rio Santa delta inland as far as he could see. Photographs taken on a later flight and research conducted on the ground revealed a seven- to 15-foot-high stone wall—apparently some kind of boundary—that stretched for 40 miles. Fourteen hilltop forts, not visible from the Rio Santa valley, were strung along the wall. Recent archaeological work indicates that the Great Wall of Peru pre-dates the Inca and the Chimu empires, with some wall sections dating back to 650 AD.

The expedition completed its work in the north in May 1931. The team then headed south and made several flights into the Andes mountains to prepare for the survey of the Colca Valley. The

The expedition took over 1,000 ground shots; the one below shows an 18th century church in the village of Maca. Six decades later an earthquake left the church badly damaged (bottom). Signs of the terrain's instability are also evident in the valley's main road (left).

NEG. #BB745/COURTESY AMERICAN MUSEUM OF NATURAL HISTORY

F.C. ENGLE (2)

NEG. #334682/COURTESY AMERICAN MUSEUM OF NATURAL HISTORY

Johnson took this oblique shot showing Maca (foreground) and Lari, villages that, like others in the valley, were laid out in a grid pattern imposed by Spanish colonial administrators. The valley's agricultural terraces, on the other hand, which appear as a series of ridges, date back to pre-Incan civilizations. Opposite: Shooting from a vantage similar to Johnson's, the author took a photo showing that many of the terraces below Lari have collapsed, most during a 1991 earthquake.

group made its first high-altitude landing on a road near the city of Huancayo, 11,000 feet above sea level. Shippee, impressed by the event, wrote that the "first attempt at Huancayo will always be remembered. In landing at such heights the speed of the plane is nearly doubled.... In the thin air one has to be careful with the controls. The plane will stall with no warning, and sharp turns are dangerous...."

A few weeks after the landing, the *New York Times* ran a story headlined "Shippee, Explorer, In Andes Air Crash." During a flight to the city of Cuzco the *Washington* had run out of fuel and the pilot had had to make a forced landing in a region of the Andes. A two-foot section of the airplane's left wingtip was broken off.

In Cuzco the expedition aircraft swapped wings so that the *Washington* could continue its photographic mission. Shippee and Hay were to fly the *Lima*, now outfitted with the damaged wing, to Arequipa for repair. Shippee later wrote, "We were none too sure about how it would fly.... We waited and waited for the darn thing to lift, but it was like lead. Our only hope was hop the wall [at the end of the field] and cut the gun, landing in the corn field beyond." But in the attempt, the aircraft's undercarriage was torn off, Shippee and Hay were badly bruised, and the *Lima* was nearly totalled. The remains of the aircraft were crated up and shipped by rail to the coast.

After arriving in southern Peru the expedition began to search for a site in the Colca Valley where an airplane could land. Such a site would be useful for communication between the pilot-photographer team and the ground party.

Shippee and expedition engineer Van Keuran traveled by train, truck, and burro to Chivay, the valley's largest village. After scouting the valley for several weeks, they found a potential landing site on a dry lakebed near the village of Lari. In the Colca a strong, steady wind blows up-valley in the afternoon, and at Lari a runway could be built aligned with the winds.

Shippee negotiated with Lari's mayor for workers to build a 4,000-foot dirt airstrip. He got 165 workers to put in eight days of labor. Total cost: six dollars' worth of *chicha*, a gray viscous corn beer.

Meanwhile, Johnson flew out from Arequipa to conduct an aerial survey of the Colca Valley. He also dropped mail for his colleagues in Chivay's plaza. The *Washington* retrieved messages that the ground team left in a pouch hung from a wire strung between the two towers of the town's church. The airplane extended a pole with a hook that grabbed the wire, and someone in the plane would lean out and snatch the pouch. Shippee later wrote that most of the messages contained requests for "socks and whiskey."

On July 6, 1931, Johnson arrived in the valley by burro. Preparations were made for the *Washington* to make a landing at Lari. But when pilot Irving Hay

F.C. ENGLE

saw the airstrip, he didn't think it looked safe to land on, and he flew back to Arequipa. The expectant crowd, primed for the arrival with *chicha*, turned on Shippee and Johnson.

The two succeeded in calming the villagers and promised that the airplane would return—and land—in a few days. They were true to their word. William Runcie, cinematographer and late addition to the expedition, recorded the landing and the welcoming fiesta. The mayor presented the explorers with a young goat, which Shippee and Johnson took with them when they departed in the *Washington*.

The expedition returned to New York on September 7, 1931. That evening they were interviewed by Lowell Thomas for an NBC radio broadcast. Shippee then went on the lecture circuit and wrote articles on the expedition for *National Geographic* and the American Geographical Society's *Geographical Review*.

In eight months in Peru, the Shippee-Johnson expedition had shot 3,000 vertical and oblique aerial photos, 1,000 ground photos, and 30,000 feet of motion picture film. Most of the archive now resides at the American Museum of Natural History in New York, and before our own team traveled to the valley in 1997, we studied the collection and made copies of the aerial photographs to bring with us.

When we arrived in Arequipa, which is 8,000 feet above sea level, we stopped for two days to acclimatize to the altitude. Then we went by "chicken bus"—one jammed with people, belongings, sacks of agricultural products, and occasionally farm animals—over dusty washboard roads to the Colca Valley. We arrived in the village of Lari after dark.

Don Esteban, Lari's *alcalde*, or mayor, beamed when I showed him a copy of the 1934 article Shippee had written on the valley for the *National Geographic*. In a region where major events are usually earthquakes, epidemics, or droughts, the landing of the *Washington*, captured in a photograph in the magazine, was significant in Lari's 400-year history. During our stay, we did not meet anyone in the village who was old enough to remember the Shippee-Johnson expedition—life expectancy for males is about 55 years—but everyone had heard stories from their parents.

Don Esteban helped us to find a guide and pack animals. Prospective guides shuffled into a room lit by one candle. In broken Spanish we talked about the route over the high pass above town, the relative merits of burros versus horses, and the fee we would pay. In Quechua, the language of the Incas, Don Esteban explained our plan to the men, and soon we had a guide and three burros.

In the following days, as we made observations on foot and interviewed the valley's residents—a process known as ground truthing—we realized that the reports of Sabancaya erupting and unleashing killer mudflows were wrong. The destruction we observed—cracked and collapsed agricultural terraces and buildings—was due to a 1991 earthquake. Across the valley, the village of Maca had been leveled and 20 people had been killed. In Lari the homes and the church were spared, but the village had lost about 30 percent of its agricultural terraces.

For our aerial work, we had chartered an airplane and pilot in Arequipa. To facilitate comparisons, we tried whenever possible to photograph from the same altitude and azimuth that Johnson had used. But Shippee and Johnson had the better aircraft for aerial

photography. Despite the best efforts of our pilot, Carlos Catarani, our Piper Cheyenne III could not fly as slow as the *Washington*, so we had less time to frame and shoot. In addition, we had to shoot through plexiglass windows that couldn't be opened and sometimes had sun glare, whereas when Johnson wanted to take oblique-angle photographs, he could open the Bellanca's windows.

As we flew over the valley, alarms sounded continuously from the cockpit. When we wanted to slow the aircraft to shoot photos, Carlos would abruptly cut power to the engines, an action that set off a warning to lower the landing gear. We had a lot of confidence in Carlos. Peru maintains an air force, the Fuerza Aerea Peruana, which it uses principally in border clashes with Ecuador, and Carlos had flown the Soviet-built Sukhoi Su-22 as a ground attack pilot. Low-level flying, which we required for our observations, was something he excelled at.

From the air, the valley appeared much the same as when Shippee and Johnson flew over it. The few noticeable changes were an unpaved road where there had once been a llama trail, and occasional openings in a large irrigation tunnel that bypasses the valley on its way to the desert piedmont.

As we flew 400 feet over Sabancaya, we saw fumaroles—vents of steam and gas—rising from the crater walls, and fresh cones of debris on the crater floor. Had we been standing on the crater rim, much of what we were seeing would have been obscured. And satellites would have missed such small features altogether. Aerial observation is an essential intermediate level between ground truthing and satellite remote sensing.

Johnson's oblique aerial photographs showed Sabancaya as an ice-covered dome. Today it is a crater shrouded in a thick layer of ash. The great icecaps

NEG. #BB65/COURTESY AMERICAN MUSEUM OF NATURAL HISTORY

NEG. #BB47/COURTESY AMERICAN MUSEUM OF NATURAL HISTORY

The 1931 expedition hired villagers to clear an old lakebed in Lari for use as an airstrip. After landing there, Shippee (top, left) and Johnson posed with the workers. Perched on the camera is Pibe, the expedition's mascot.

present on nearby mountains in 1931 are now trickles of rapidly receding glaciers. Since about 1900, the region has been getting warmer and drier, a process that seems to be accelerating. Is this change an indication of a global trend? Climatologists at the University of Colorado are trying to answer these questions, and they are relying in part on the Shippee-Johnson photographs.

As for our study, with support from NASA's Commercial Remote Sensing Program and Trimble Navigation Ltd., the Colca Valley Geohazards Project is now under way. We are comparing the latest satellite imagery with the 1931 photos to detect and measure change due to landslides and slumps in the valley. Peruvian scientists are collaborating with us, and we are sharing our data with civil defense officials in the valley. Though aerial photographs and satellite images cannot be used to predict earthquakes or eruptions, they can be used to model what will happen when these processes occur. A digital terrain model can show the most likely path of a mudflow racing into the valley from Sabancaya, for instance—information useful for evacuation planning.

After returning to the States, Shippee and Johnson continued their partnership for several years. They formed a company, Aerial Explorations, that specialized in aerial photography; their assignments included photographing state and national forests and other natural resources. During World War II Shippee served as an Army Air Forces intelligence officer stationed in Wash-

ington, D.C. After the war he worked as a marketing analyst for United Airlines' commuter service.

Johnson continued his part-time military career with the 44th (aerial) Division of the New Jersey National Guard. One November afternoon in 1933 he took off from the Red Bank Airport in one of the Guard's observation aircraft, a Douglas-designed O-38B. His observer, Sergeant Alfred Poole, was testing a new camera system. Moments after takeoff the aircraft lost power and plunged into a house. When leaking fuel from the aircraft reached the kitchen coal stove, the house burst into flames. The five people inside and the two men in the airplane were all killed.

Shippee died in 1989. Just before his death, he was contacted by University of Wisconsin geographer William Denevan, who was heading up one of the first research projects in the Colca Valley: a study of population decline after the Spanish conquest. Denevan was using the Shippee-Johnson photographs. He recalls that Shippee, on hearing that the photos were being used for research, was "pleased that he and Johnson had not been forgotten."

Long after the Shippee-Johnson expedition had left, the people of Lari continued to maintain the runway there, hoping that other aircraft would land. But when an airstrip was built at Chivay, the provincial capital, in the late 1980s, it became apparent that Lari's would remain unused.

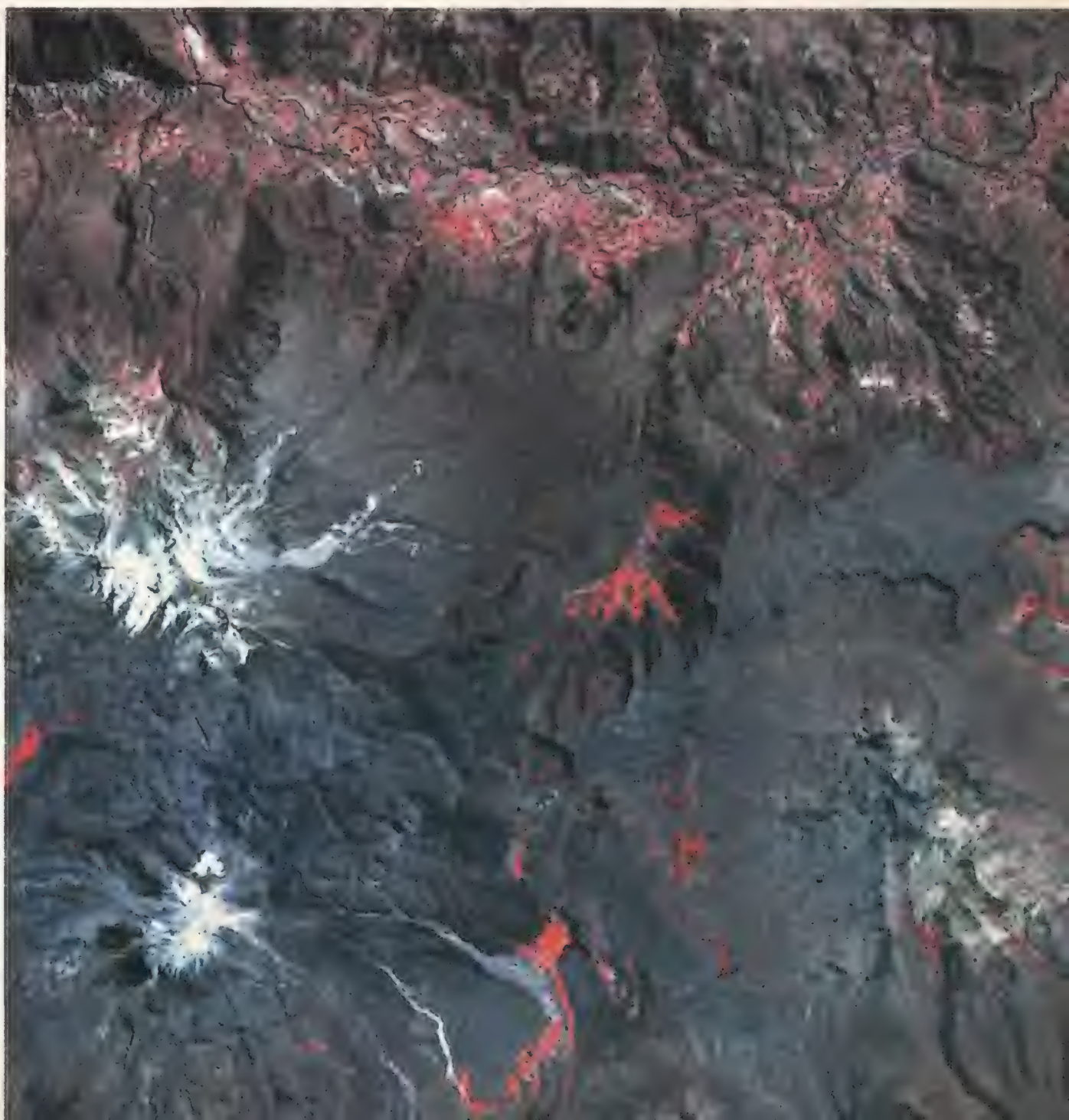
I recently walked over the now-abandoned strip. I looked for the runway markers Shippee had etched into the gypsum-rich soil, but they were gone. Four earthen reservoirs for storing irrigation water are now under construction at the site. We can see the reservoirs in our most recent satellite image; it's the latest change in the "lost valley."

The Colca is slowly being transformed as adventure tourists arrive and power lines extend into the valley. Yet even today most of the residents live in small villages and work in a cycle of cultivating crops on the terraces during the wet season—November to May—and herding alpacas on the uplands during the dry winter months. It's a cycle that has lasted for at least a thousand years.

Nonetheless, as Shippee noted in 1931, "One could spend a lifetime in the Colca finding every day something of new interest." One recent discovery: a pre-historic obsidian quarry. Obsidian is a glassy volcanic rock from which stone tools were made, and obsidian from this quarry has been found at archaeological sites in southern Peru and Bolivia. This discovery indicates that the valley was a major source of stone tools and suggests that it was an important pre-historic trading route.

What, ultimately, did the Shippee-Johnson expedition contribute? One essayist, writing in the *New York Times* three weeks after the team had returned home, declared: "The value of these expeditions is not alone in the intrinsic worth of what they add to the known. [Earth's] distinction is that...it has bred creatures capable of reason, endowed by the mystery of the mind's desire, and imbued with a religion that is a product of the relation between the human mind and the environment. This is the justification of such perilous striving to know all our environment, from a hidden valley on the globe to the remotest galaxy...."

On a more practical scale, I can say that for our study, the Shippee-Johnson images are crucial. They provide us with a detailed baseline from which we can measure change over the course of six decades. And from these measurements, we will be able to make recommendations that will, we hope, help the residents understand and cope with the region's dangers while living among its distinctively beautiful and fascinating landscape.

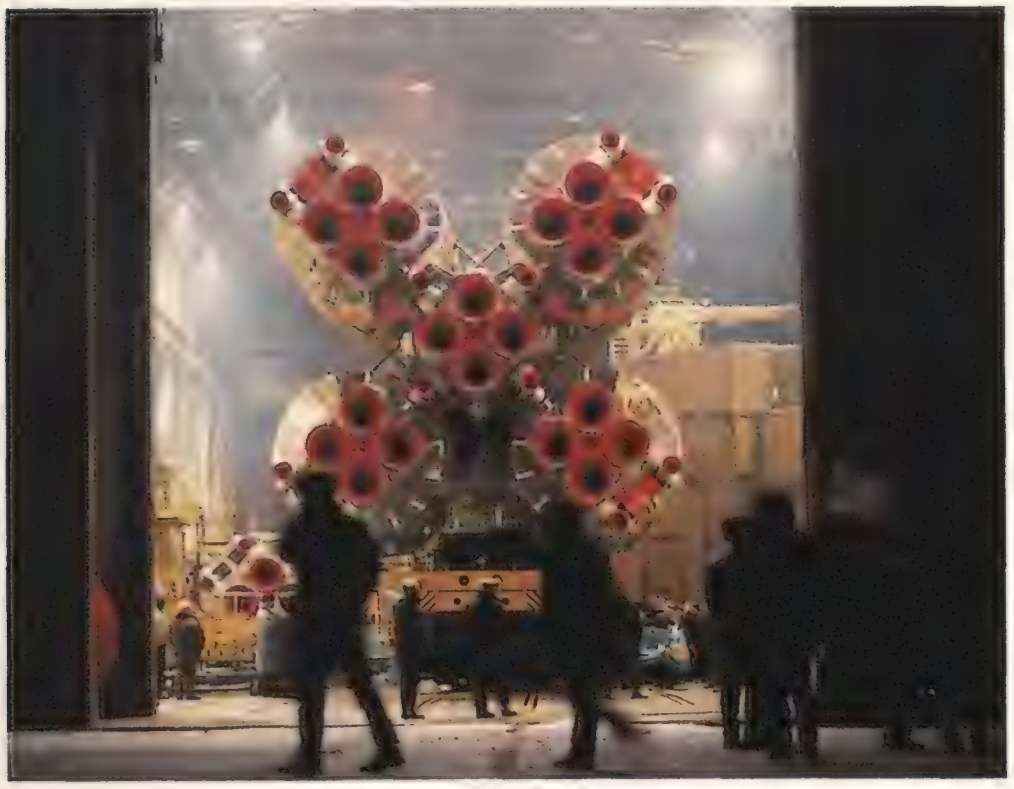


NASM/CEPS AND SPOT IMAGE

Last September the SPOT satellite acquired this image (shown with false color) of the middle Colca Valley and surrounding highlands. The bright red areas are wetlands, watered by melting snow on the volcanoes. Comparing this image to the space shuttle photo (pp. 72-73), taken at the same time of year, shows that the snow cover has diminished over the course of a decade.

>SIGHTINGS<

Long a deep, dark, cold war secret—and in the 1970s the world's most prodigious launch center, with launches every three to four days—the Baikonur Cosmodrome in central Kazakhstan now exists primarily to send up the Soyuz workhorses that carry Progress freighters to replenish the Mir space station, along with the occasional Proton satellite hauler. On nine launch complexes, a rail system connects the launcher and satellite assembly buildings with 15 pads, where a mostly Russian workforce has launched over 1,000 Soyuz rockets. Surreptitious tradition dictates that the rocket and its payload be assembled and hauled to the pad on its side in the dark of night. Rocket scientists from the Soviet Union's glory days would spin like gyros in their graves if they heard that a version of the venerable Soyuz is now being marketed by a branch of Arianespace.



FRANCIS DEMANGE/GAMMA (4)

TARGET: HOLLYWOOD

Rocket Boys: A Memoir *by Homer H. Hickam Jr. Delacorte Press, 1998. 368 pp., $23.95 (hardcover).*

The first rocket blew apart his mother's garden fence. The second one "emitted a boil of nasty, stinking, yellowish smoke and then fell over." The third burst into fragments on the ground.

But Homer Hadley Hickam Jr.—14-year-old son of the mine superintendent in Coalwood, West Virginia—was bent on learning "the blamed secret that made a rocket fly." From 1957 to 1960, he battled his disapproving father, his own self-doubt, and a local culture that prized football over physics, all so he could master the mysteries of propulsion. By the time he graduated from Big Creek High School, Hickam and a band of fellow rocketeers were launching homemade missiles that rode thundering geysers of smoke and flame to disappear six miles high.

Rocket Boys, a book that lifted off as an article in these pages ("Big Creek Missile Agency," Above & Beyond, Feb./Mar. 1995) and reached its apogee as the film *October Sky* earlier this year, is Hickam's gritty memoir of how he reached those heights. Although it contains enough details of missile design and construction to satisfy the geekiest aerospace cadet—this is rocket science, after all—the book also conjures locale and character with a lyrical mastery you might not expect from a techie (the author went on to become a NASA engineer; his memoir was nominated for a National Book Critics Circle award).

The Coalwood of Hickam's re-creation is a company town of 2,000 souls living in company houses "painted a company white, which the blowing coal soon tinged gray." Hickam recalls how dust from the soft, bituminous coal was so pervasive that "miners walked around with their eyes lined like Cleopatra's."

One night in early October 1957 the murk is pierced by the reflected light of Sputnik, which Hickam spies as a "bright little ball, moving majestically across the narrow star field between the ridgelines.... I had never seen anything so marvelous in my life."

LINDA TERRY

Homer Hickam's youthful adventures with homemade rockets (above) were the basis for "Big Creek Missile Agency" (Feb./Mar. 1995), which in turn inspired the book Rocket Boys *and the film* October Sky.

Inspired to build and fly rockets of his own, Hickam forms a club—the Big Creek Missile Agency—and drafts co-conspirators. There's excitable O'Dell, son of the town garbageman and therefore the BCMA's Chief Metal Scrounger; polio survivor Sherman, practical and orderly; and randy Elvis look-alike Roy Lee, whose mechanical aptitude finds an outlet in his single-handed decoupling of brassiere hooks.

The BCMA's initial efforts fizzle on the launch pad until Hickam recruits Quentin, the class joke and the school genius. Quentin is both spur and scold, keeping Hickam—and his rockets, all dubbed "Auk" after the flightless bird—on course. After Auk XXII tops out at 5,776 feet above "Cape Coalwood," Quentin goads Hickam into solving the differential equations needed to design a de Laval nozzle that could send a rocket twice that high.

They surpass that goal and embark on a manic quest for maximum altitude, experimenting with increasingly powerful propellants. These range from simple black powder (saltpeter, sulfur, and charcoal) to pink-flamed "rocket candy" (potassium nitrate and melted sugar) to "zincoshine"—a volatile gumbo of zinc, sulfur, and local moonshine. The results are often explosive and never predictable. The payoff is worth the pandemonium, however: Auk XXXI, the boys' final rocket, reaches 31,000 feet.

Ultimately, Hickam prepares an exhibit for a local science fair ("A Study of Amateur Rocketry Techniques") and makes it to the national finals. It is tempting—and just—to grant his memoir the same distinction earned by his display: "Outstanding in the Field of Propulsion."

—Allan Fallow was a staff writer and editor for Time-Life's "Epic of Flight" and "Voyage through the Universe" series.

Glen Edwards: The Diary of a Bomber Pilot *by Dan Ford. Smithsonian Institution Press, 1998. 224 pp., b&w photos, $24.95 (hardcover).*

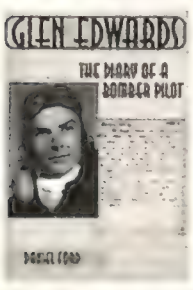
"Darndest airplane I ever tried to do anything with. Quite uncontrollable at times," wrote Glen Edwards after a particularly hairy outing in the Northrop YB-49 flying wing—the aircraft that would soon take his life.

Diary of a Bomber Pilot is the account of the man whose name is forever attached to test flying in the high desert of California. Edwards' simple, gentlemanly manner is nicely complemented by Dan Ford's research and interviews with surviving family and colleagues.

Edwards' diary started on June 13, 1941, as he began flight training at Cal Aero Academy, a civilian company in Chino, California, that trained fliers for the Army. His entries over the following two years outlined his combat missions in North Africa and Italy.

By 1944, Edwards was at Wright Field in Dayton, Ohio, where he embarked on his career as a test pilot—the start of a journey that would lead him to Muroc Army Air Field in California, home to a new generation of jet and rocket-propelled aircraft. In 1950, that desolate place would be renamed Edwards Air Force Base, or more simply "Edwards."

Ford's commentary is an unobtrusive and welcome voice throughout. We learn the complexities behind Edwards' understated contention that the YB-49 Flying Wing was a handful, most notably in its frightening stall behavior: The



aircraft would give no buffet or vibration, the nose would rise, and the Wing would become immune to all control inputs as it went vertical and rotated backward like a pinwheel. Earlier, Bob Cardenas and Danny Forbes (the namesake of Forbes Air Force Base in Kansas) had encountered this terrifying tendency while stalling the YB-49 at 40,000 feet and took nearly every foot of that altitude to recover the aircraft. On the day Edwards and four crewmen died while stalling the big wing at just 15,000 feet, the margin was too thin for survival.

After the reader sweats Edwards' combat missions, Stateside romances, and everyday problems, the experience of reading his final entry, written three days before his death, is chilling. But throughout, the words of Edwards and Ford combine into a fascinating tale and a tribute to an unassuming man who simply loved to fly.

—John Sotham is an associate editor at Air & Space.

This New Ocean: The Story of the First Space Age *by William E. Burrows. Random House, 1998. 723 pp. $34.95 (hardcover).*

In sprawling, epic style, William Burrows offers a finely detailed popular account of our venture into space, from ancient conceptions to the 1990s. And like a good epic, the author's story focuses on the ambitions, motives, and accomplishments of a unique generation: the people who in a span of less than 40 years transformed space exploration from a dreamy concept into reality. Their efforts, inseparable from the cold war and American-Soviet competition, compose what has become the first Space Age.

The author's story concentrates on the military and cold war foundations of the space enterprise in the years after World War II, its heyday through Apollo, and the compelling science explorations of the 1970s and 1980s—Viking, Voyager, Hubble, and others. In this material, *Air & Space* contributor Burrows is at his best, weaving together the contributions of government, industry, and academia, of cold war pragmatists and dreamers, and of big national programs and flesh-and-blood individual contributors. Using a wide range of secondary literature, interviews, and archival documents, Burrows manages a difficult balance: to convey the spectacular accomplishments of the Space Age as well as the sometimes messy politics and motives behind the American and Soviet efforts.

These narrative skills shine in lively, accurate renderings of two crucial and tangled sagas: the period before and after Sputnik, as guided missiles, nuclear weapons, science and reconnaissance satellites, and cold war politics shaped early space policy, and the 1960s race to the moon and to spy from space. Burrows' treatment of the accomplishments of recent years is less rich, tending toward a catalog of programs.

This New Ocean, one of three finalists for this year's Pulitzer Prize in history, well achieves its goal: to compose the disparate stories of the first generation of space activity into a coherent, robust tale.

—Martin Collins is a curator in the space history department of the National Air and Space Museum.

Beyond the Horizons: The Lockheed Story *by Walter J. Boyne. St. Martin's Press, 1998. 533 pp., color and b&w photos, $29.95 (hardcover).*

Edwin Land, inventor of the Polaroid camera, would play a key role in the development of classified U.S. aircraft and satellite reconnaissance. And secrets behind the F-117's stealth capabilities were the unwitting gift of Soviet scientist Pyotr Ufimtsev. Such little-known gems sparkle throughout Walter Boyne's *Beyond the Horizons: The Lockheed Story.*

Boyne, prolific aviation writer, former director of the National Air and Space Museum, and founder of *Air & Space,*

FLYING COLORS

The Mighty Eighth in Art *by Roger Freeman. Arms & Armour/Sterling Publications, 1998. 160 pp., $24.95 (paperback).*

Opening this book resembles—and is meant to—looking through the Perspex windscreen of a P-51 or the greenhouse of a B-17 or Lancaster, gazing into a nether world of alternating tranquility and horror.

In this paperback edition of his 1996 release, popular military writer Roger Freeman has assembled 75

works produced by various artists during and after World War II. Most paintings chronicle real combat events, but there are also quiet pub scenes and misty visions of empty airplanes in repose or being prepped for missions. The text is worthy too—though modestly dubbing himself a "compiler," Freeman explains each painting in plentiful detail.

—David Walsh's uncle racked up 50 missions as a B-24 pilot.

Aviation Art *by Michael Sharpe. Thunder Bay Press (distributed by Advantage Publishers Group: 800-284-3580), 1998. $24.98, 208 pp., (hardcover).*

This new collection of 175 paintings features large, crisp, and colorful reproductions that are seldom run across the page gutter. The text is

generally accurate, although some aircraft are mislabeled: F-15 Eagles are identified as F-14 Tomcats, and an FW 190D profile is called a Bf 109G. While the book serves as a good introduction to aviation art, I would have preferred a bit more information about the individual paintings. Those familiar with aviation art will notice the absence of a dozen or so of the best known artists. But, overall, Sharpe's compilation is colorful, attractive, and reasonably priced.

—Cam Martin is the external affairs director at NASA's Dryden Flight Research Center in Edwards, California.

characterizes the aircraft industry's stunned response to the announcement of Lockheed and Martin Marietta's 1995 megamerger: Who could manage such a giant? Indeed, any chronicler of Lockheed's evolution into part of the conglomerate formed from assimilation of over 20 major companies (including General Dynamics-Ft. Worth, GE Aerospace, Loral, and LTV-Missiles) faces equivalent challenges in organizing and focusing this vast amount of information.

Of many people Boyne cites as crucial to Lockheed's corporate evolution are Robert Gross, great-hearted entrepreneur who rescued the company in 1932; Kelly Johnson and Ben Rich, contrasting geniuses who directed the Skunk Works; and Dan Haughton (seen as a classic workaholic micromanager), who persuaded the British government to rescue Rolls-Royce, thereby enabling the U.S. government to save Lockheed by guaranteeing loans for the L-1011.

Despite the book's wealth of information, readers will find an index containing only people's names and will notice some factual slips: 26,000 tons of thrust listed for an early J-58 engine; a caption referring to the U-2 as "the only aircraft that the USAF ever reintroduced into production," even though an additional 50 C-5B Galaxies began rolling off Lockheed's assembly line 12 years after the final C-5A in 1973.

And why no mention of the superb Lockheed KH-12 reconnaissance satellites and Lacrosse imaging radar satellite? The arms purchases of the Reagan years contributed to our massive national debt—but also to the collapse of the Soviet Union, which bankrupted itself trying to match such increasingly sophisticated military technology and field it. In that process, Boyne contends that Lockheed "was in great measure directly responsible for the victorious outcome of the cold war."

Hyperbole? He correctly describes Lockheed (from the 1960s to the Gulf War) as: sole source of primary U.S. military airlift capability, lone supplier of our submarine-launched ballistic missiles (their assured second-strike capability a powerful deterrent), builder of the only current U.S. fixed-wing anti-sub aircraft, and provider, through the U-2, SR-71, and numerous spy satellites, of unprecedented electronic and photo intelligence.

All from one company—no exaggeration.

—Theodore L. Gaillard Jr. is a Philadelphia-based writer specializing in technology and military issues.

Lindbergh *by A. Scott Berg. G.P. Putnam's Sons, 1998. $30.00 (hardcover).*

Few recent biographies have generated the enthusiasm and admiration that greeted A. Scott Berg's *Lindbergh.* Benjamin Schwarz of the *Los Angeles Times* pronounced it "one of the most important biographies of the decade" and "an extraordinary achievement." Historian Doris Kearns Goodwin and the Kirkus Review agreed that the book is "magisterial."

Lindbergh was making news long before it was published. The book world sat up and took notice when it was announced that Anne Morrow Lindbergh had granted full access to her husband's voluminous papers—and her own—to Berg, the award-winning biographer of the legendary Scribners editor, Maxwell Perkins, and Hollywood mogul Samuel Goldwyn. Then came reports of a record-setting book advance, followed by the news that Steven Spielberg was interested in acquiring the film rights even before he had read a single word of the text. Finally, news reports suggested that the film deal had mysteriously collapsed.

While the book is enormously detailed, it holds few real surprises for readers familiar with Lindbergh's story, or with the history of flight in America. The most important bits of fresh information, from an account of the failed political career and checkered marital history of grandfather August Lindbergh to the revelation of Anne Morrow Lindbergh's 1950s love affair with a New Jersey physician, are far from the central issues of the book.

Even readers who, like this reviewer, decide that *Lindbergh* does not quite live up to the hyperbole of the reviews will certainly recognize that it is a book well worth waiting for. Berg offers a cradle-to-grave biography that opens in 1859 with the arrival of a family of Swedish immigrants on American shores, and carries the reader forward to the burial of aviation's greatest hero in an out-of-the-way cemetery on the coast of Maui, overlooking the Pacific. He charts the trajectory of Lindbergh's life, and that of his family, against the backdrop of 20th century America and Europe.

Berg identifies the anti-Semitic elements in Lindbergh's public statements prior to the entry of the United States into World War II, but argues that he was not pro-Nazi. Fair enough, but the author might have shared some of Lindbergh's deeper thoughts on race and

FROM AIR UNIVERSITY PRESS

The Development of the B-52 and Jet Propulsion: A Case Study of Organizational Innovation *by Dr. Mark D. Mandeles. Air University Press (334-953-2773), Maxwell Air Force Base, Alabama, 1998. 208 pp., $13.00 (paperback).*

The first three chapters of this volume center on management dynamics, so the aviation enthusiast would do well to skip straight to chapters 4 and 5, which contain a detailed and illustrated—but easily read—history of the different models of the B-52 and other strategic bombers in development or in use during the 1950s, such as the B-29, B-50, and B-36. The book recounts how the seemingly timeless B-52 evolved over time to meet changing engineering and military requirements. Chapter 6 discusses the effects of organization decision making on complex weapon systems, and provides recommendations for future acquisition programs.

—Rolfe L. Hillman III has reviewed books for the Naval Institute's Proceedings *and* Naval History.

The Army and Its Air Corps: Army Policy toward Aviation, 1919–1941 *by James P. Tate. Air University Press (334-953-2773), 1998. 210 pp., $14.00 (paperback).*

The Army and Its Air Corps was James P. Tate's doctoral dissertation at Indiana University, but unlike many such works, it is very readable. In it, he describes the U.S. air arm's slow journey to independence.

Tate recounts how visionaries like General William "Billy" Mitchell testified before Congress, and gave public air power demonstrations to get the Army to make fuller use of its aircraft. When President Franklin Roosevelt expanded the Air Corps in 1939, a nucleus of generals arose who provided the direction for victory in World War II, as well as the creation of the Air Force in 1947.

—Colonel Calvin Bass (U.S. Air Force, ret.) flew 864 combat missions in Vietnam and reviews books for Aviation History *magazine and the* Tulsa World.

civilization with his readers. "Aviation," he explained in a 1939 *Reader's Digest* article, was "a gift from heaven to those Western nations who were already strengthening their dominance over other people." The airplane was "a tool specially shaped for Western hands, a scientific art which others only copy in a mediocre fashion." Flight, he concluded, was "one of those priceless possessions which permit the White race to live at all in a pressing sea of Yellow, Black, and Brown." Lindbergh never retracted those words, and this biography would have been even better balanced had the author shared them with his readers.

Berg is at his best when describing the private Lindbergh, the man of enormous strengths and deep flaws. The son of a mismatched couple, he grew into a shy, distant, and emotionally restrained man. "Aviation created a brotherhood of casual acquaintances in which he felt comfortable," Berg explains. Much of Lindbergh's life seems to have been a struggle to find a middle ground between his deep desire for privacy and the need to use his public image to shape opinion and effect change.

"For me," the author has remarked, "their marriage is the most interesting aspect of the biography." Even those readers who are captivated by the public career of Lindbergh the aviator will agree. The story of the turbulent relationship between Charles and Anne Lindbergh holds the narrative together.

Ultimately, Berg is a deeply admiring biographer. While admitting that "there were times when [Lindbergh] was terribly wrong, sometimes stupid, sometimes offensive," the author argues that he was a man who sought to make the world a better place. "I've taken lessons from him on how you live your life, what you do with it, and how much you can pack into it," Berg comments.

Lindbergh is both a powerful and a very readable book. Those who contend that this is the definitive biography of the quintessential aviator are wrong, however. The life and times of Charles Lindbergh has the quality of an American myth. It is an enormously compelling story that illuminates both human nature and our national character. This is not the first time that it has been told, nor will it be the last. For the moment, however, *Lindbergh* stands as the most detailed and readable account of one of the most extraordinary lives of the American century.

—Tom D. Crouch is the senior curator of the aeronautics department at the National Air and Space Museum.

June 4–6
World War II Weekend. Mid Atlantic Air Museum, Reading Regional Airport, PA, (610) 372-7333.

June 13
Aurora AirExpo Fly-In Pancake Breakfast. Aurora Municipal Airport, Sugar Grove, IL, (630) 466-4579.

Spencer Flagfest Airshow. Spencer Municipal Airport, IA, (712) 264-3107.

June 17–20
American Waco Club Fly-In. Creve Coeur Airport, MO, (616) 624-6490.

June 19 & 20
EAA Antique Classic Chapter 7 Fly-In and Pig Roast. Aeroflex Airport Andover, NJ, (908) 832-7167.

Tristate Warbird Airshow. Mountain City, TN, (423) 727-5460.

Wings Over Moffett Airshow. Moffett Field, CA, (408) 998-5433.

June 26
EAA Chapter 1250 Fly-In Flea Market. Pottstown-Limerick Airport, PA, (610) 933-1359.

July 2–5
Taildraggers Fly-In. Footlight Ranch, Wellsville, PA, (717) 432-4441.

July 3
EAA Chapter 690 Airplane Wash and Fly-In Pancake Breakfast. Briscoe Field, Lawrenceville, GA, (770) 394-5466.

July 3–5
The Great War Fly-In & Concourse. Creve Coeur Airport, MO, (314) 638-1550.

July 4
Rockport-Fulton Fourth of July Airshow. Rockport, TX, (361) 729-6201.

July 10
Grass Valley AirFest. Nevada County Airport, Grass Valley, CA, (530) 273-1972.

July 10 & 11
History of Flight Airshow. Geneseo Airport, NY, (716) 243-2100.

Wings of Victory Airshow. Fairfield County Airport, Lancaster, OH, (740) 689-9245.

July 17
Lions Club Fly-In Fish Boil. Washington Island Airport, WI, (920) 847-2770.

Car Talk. R. Dale Reed began working at what became the NASA Dryden Flight Research Center in 1953. He conducted aerodynamic loads research on the X-1E, X-5, F-100, and D-558-II and performed aerodynamic heating measurements on the X-15 before he began implementing the lifting body program.

The Little Engines That Could. Contributing editor Stephan Wilkinson has a thing about engines of all sizes.

Mustang Mania. Linda Shiner is the executive editor of *Air & Space/ Smithsonian*.

Further reading: *P-51 Mustang Restored*, P. Coggan, Motorbooks, 1995.

The Terrible Two. Billy Goodman writes about science and technology for adults and children and is online at bgoodman@nasw.org.

Aero Acres. John R. Breihan is a professor of history at Loyola College in Baltimore, Maryland, and co-author of *Martin Aircraft 1909–1960*. In 1996-97 he was a National Air and Space Museum Verville Fellow, researching World War II aircraft workers' housing.

Night of the Shooting Stars. Andrew Lawler is a writer for *Science*; currently, he is a Knight science journalism fellow at the Massachusetts Institute of Technology.

Drugnet. Frequent contributor Joseph Bourque logged 34 hours in various U.S. Customs aircraft during the research for this article.

Strong Arm. Tom Harpole writes frequently for *Air & Space* and is blessed with two good arms to do so.

The Fly Chromosome. A former Air Force intelligence officer, Reina Pennington is a candidate for a Ph.D. in history at the University of South Carolina.

Secrets of the Colca Valley. Frederick Engle is a geographer at the National Air and Space Museum's Center for Earth and Planetary Studies. For help with this article, he thanks Richard Allen, Dan Buck, Dorothy Cochrane, Bill Denevan, Ron Davies, Dan Hagedorn, Carolyn Russo, Sam Smith, and Marilyn Shippee.

California Dreaming. Becki Bell is a freelance writer living in the San Francisco Bay area.

"UNIDENTIFIED FLYING OBJECT" OFFICIAL CONTEST RULES

1) NO PURCHASE NECESSARY

2) To enter hand print on a 3 1/2" x 5 1/2" postcard your name, address and telephone number, date of the issue cover, correctly identify the "unidentified flying object" illustrated, and be sure to follow instructions on the feature page. No mechanically reproduced entries permitted. You may enter as many times as you wish, but each entry must be mailed separately.

3) Each entry must be postmarked no later than the last day of the month on the issue cover and received by the 10th of the month following the issue date. Mail entries to: Air & Space/Smithsonian Magazine Contest, 901 D Street SW, 10th Floor, Washington DC 20024.

4) Six contests: (1) December 1998-January 1999, (2) February-March, (3) April-May, (4) June-July, (5) August-September, (6) October-November 1999 issues.

5) One winner will be randomly selected from all correctly answered entries from each of the six contests by Marden-Kane, Inc. an independent judging organization whose decision in all matters relating to the rules and administration of the contest is final and binding. Each of the six contests' winners will be awarded a Garmin 111 Handheld Satellite Navigator, approximate retail value $350.00 each.

6) SECOND CHANCE GRAND PRIZE DRAWING. In addition to the prize awards for the six contests, a "second chance" random Grand Prize drawing will take place on December 10, 1999. All eligible entries from all six contests will be automatically entered in the Grand Prize drawing. The prize...a $2,000 voucher for flight training provided by G. A. Team partner flight training facility. Winner will be provided with a list of facility locations. Transportation to and from the facility not included. Total A.R.V. of prizes $4,100.00.

7) Winners will be notified by mail. All entries become the property of Air & Space and none will be acknowledged or returned. Contest open to legal residents of the U.S. and Canada 18 years of age or older at time of entry. Void in Quebec and Puerto Rico and wherever prohibited. Employees of Smithsonian Institution, advertising and promotional agencies, contributors to Air & Space and their families not eligible. Canadian winners will be required to answer an arithmetical skill question administered by mail.

8) Odds of winning each contest dependent on the number of correct entries. Taxes, if any, are the sole responsibility of the prize winner. All Federal, State, local and provincial laws apply.

9) Sponsor not responsible for damage, losses or injury resulting from the use and acceptance of a prize. Winners consent to use of name and/or likeness for editorials, advertising and promotion purposes without further compensation, except where prohibited by law. No substitution or transfer of prize permitted.

10) For a complete winner's list, available after December 10, 1999, send a stamped, self-addressed envelope to Air & Space "Unidentified Flying Object" Contest Winners, 901 D Street SW, 10th Floor, Washington DC 20024

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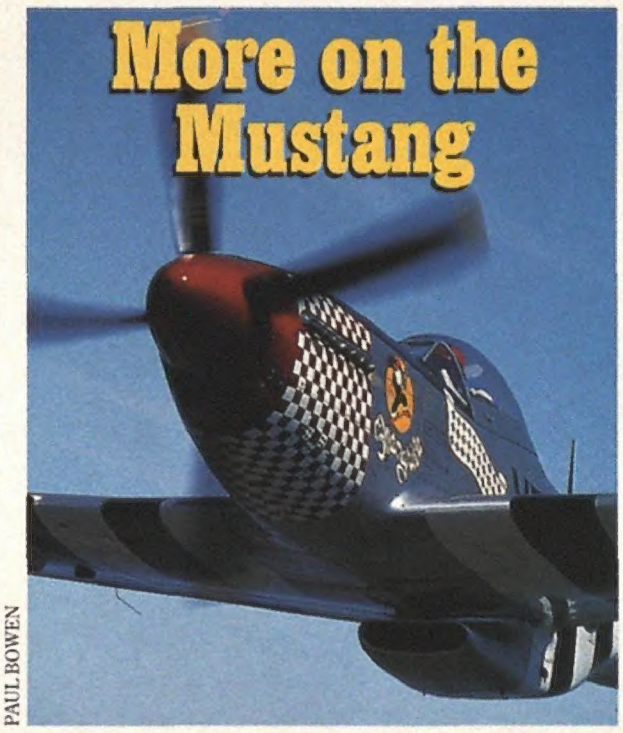


PAUL BOWEN

In correspondence with *Air & Space/Smithsonian* before he died, J. Leland Atwood described the contribution of what he called the Meredith effect to the P-51's performance. Vice president at North American Aviation when the fighter was born, Atwood had in recent years published somewhat controversial accounts of how the aircraft's engine cooling system was designed. Excerpts from his correspondence and from the seminal 1935 Royal Aircraft Establishment report by R.W. Meredith, as well as a 1998 lecture Atwood gave on the Meredith effect, are all on the Web: www.airspacemag.com/ASM/mag/supp/JJ99/Mustang.html

FORECAST

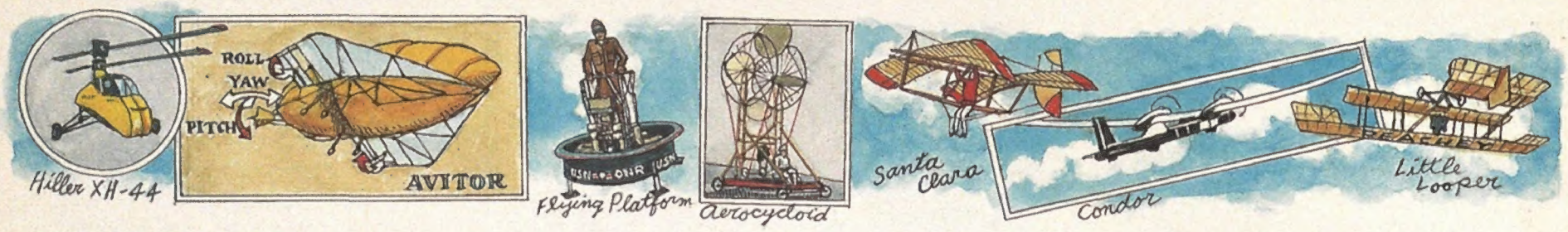
In the Wings...

Beautiful Bomber
Although the XB-70 Valkyrie, North American Aviation's Mach 3 strategic bomber, didn't make it to production, there's a little bit of XB-70 flying in today's bomber fleet.

My Laima Flew Over the Ocean
A feat of robotic derring-do.

Born-Again ICBMs
After long, gritty careers in the business of mutally assured destruction, U.S. and Russian missiles have found a new calling.

The Camera Man
We're seeing Mars like we've never seen it before, thanks largely to the efforts of one man. So why are planetary scientists miffed at him?



JOHN HEINLY

California Dreaming

It was the first flying machine to employ a three-axis system of control, and it left the ground not at Kitty Hawk but 3,000 miles to the west. The Avitor Hermes Jr. also beat the Wright *Flyer* into the air by more than three decades. Unlike the *Flyer*, however, the unmanned craft got a lot of its lift from a bag filled with hydrogen; to passersby startled by the sight of it gliding over the San Francisco Bay area, it must have looked like an overgrown, winged grub. Today, a replica of the Avitor rotates leisurely while suspended from the ceiling of the Hiller Aviation Museum, just a few miles from the site of the craft's 1869 maiden flight.

"Northern California has a cross-section of [aviation] history equal to any place in the United States," says Gordon Werne, the museum's curator of history. "Some of the first flights ever were made here." Part of the museum's purpose is to see that the region is honored for its aviation history.

The backdrop for the artifacts, a spacious building with bright walls, emulates the sky as well as an indoor facility can. Mannequins in period costume are poised throughout, giving the place the look of a three-dimensional aviator's scrapbook.

Among the first artifacts visitors encounter are replicas of gliders designed by Californian John Joseph Montgomery. The 1905 *Santa Clara* was one of the first heavier-than-air craft designed for high-altitude flight; it was launched via hot-air balloon at 3,000 to 4,000 feet. The *Santa Clara* had a three-axis control system, though it didn't seem to make the glider safe to operate: Of the two pilots who flew the fragile-looking craft, one was killed in it and the other seriously injured.

Just past the gliders is a replica of J.C. Irvine's 1908 vertical-flight Aerocycloid, which at first glance looks like a miniature amusement park ride. The Aerocycloid had a weak seven-horsepower Indian motorcycle engine and four "platens," or disks, instead of wings. Irvine designed the craft with two levers, one that warped the ends of the platens like ailerons, turning the vehicle along its longitudinal axis, and another that warped the platens forward and backward, making the aircraft pitch up or down. Despite the sophistication of its controls, Irvine's Aerocycloid never made it into the air.

Another California pioneer, Robert Grant Fowler, is remembered as the man who made the first Pacific-to-Atlantic flight, departing from California on September 11, 1911, in a Wright Model B biplane and ending in Florida five months later. The museum displays the engine that powered his craft: a four-cycle, 30-hp Wright capable of speeds of about 45 mph.

After a number of other stepping stones of early aviation—Lincoln Beachey's 1913 Curtiss pusher-like Little Looper, a restored 1935 Fairchild 24C8C—the exhibits begin focusing more on the forte of museum founder Stanley Hiller: the helicopter. Hiller, now 74, is widely acknowledged as a pioneer in rotary craft. In the 1940s, when the aviation industry was all but ignoring concepts of vertical flight in favor of building better fighters, Hiller was thinking about helicopters. "He was, I guess, what you would call a prodigy," says Werne. At the age of 17 he reasoned that the vertical directional rotors used in the tails of the helicopters of his time were hogging engine power from the lifting rotors. Hiller's one-seater XH-44 Hiller-Copter, which was completed in 1944, was the first to successfully employ two rotors that counter-rotated, so they would cancel each other's torque. An XH-44 is on display, looking a little like a small yellow dog with a flying beanie.

One of the museum's weirdest exhibits is the Hiller Flying Platform, which resembled an upside-down man's boater. The Platform had a ducted fan at its base that enabled it to make vertical takeoffs. The pilot stood in the Platform, and when he wanted to maneuver, he simply leaned in the direction he wanted to go. The shifting of his weight, in conjunction with the thrust provided by the ducted fan, did the job. Next to the exhibit, visitors can watch a video of a pilot flying the Platform around, like something out of "The Jetsons." First flown in January 1955, the Flying Platform begat the Coleopter, a Hiller design that was supposed to transition from a vertical takeoff to high-speed horizontal flight. (The prototype never was able to fly horizontally.) A replica of it has a home at the Hiller museum beside its ancestor.

Suspended from the ceiling is a Condor, an unmanned airplane with a 205-foot wingspan. Boeing built the Condor in the 1980s, funded in large part by the Defense Advanced Research Projects Agency. The defense department later decided it could not fund the Condor's maintenance, so it gave the craft to the Lawrence Livermore Laboratories in California, which in turn donated it to the museum. Packed with complex photographic equipment, the Condor was supposed to function as a high-altitude unmanned surveillance craft, though the development of sneakier, more sophisticated satellite technology made it obsolete not long after it was built. Before the remotely piloted Pathfinder vehicle knocked it from the record books two years ago, the Condor held the altitude record for propeller aircraft: 67,028 feet.

Those who won't have a chance to visit the museum can still get a quick lesson in flying, Hiller-style. Just past the drive-through of a nearby Burger King sits the UH-12E-5, a 1965 prototype of the Hiller 12E helicopters still operating today as utility craft. After stopping for lunch, visitors can have a turn at the controls of a piece of California aviation history.

—Becki Bell

Hiller Aviation Museum, 601 Skyway Rd., San Carlos, CA 94070. Phone: (650) 654-0200; e-mail: museum@hiller.org; Web site: www.hiller.org. Open every day, 10 a.m.–5 p.m. Admission: Adults, $7; seniors, $5; kids, $5–free, depending on age.

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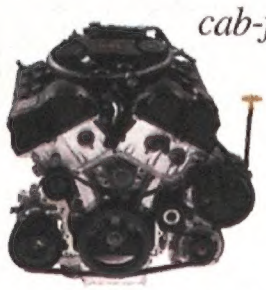
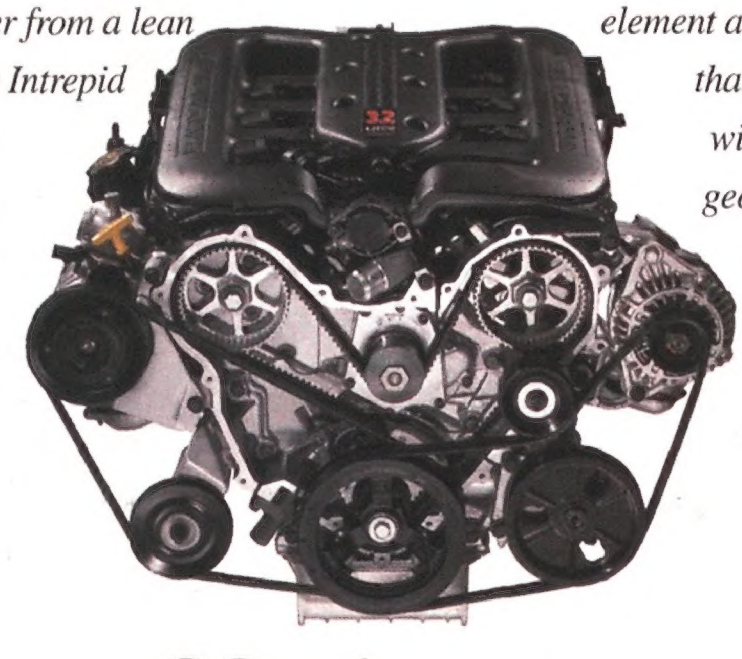
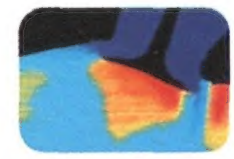
Conceived by an artful designer and exactingly rendered by sophisticated electronic tools, Dodge Intrepid's aerodynamically taut sheet metal stretches smoothly over one of the most advanced examples of cab-forward architecture yet developed.

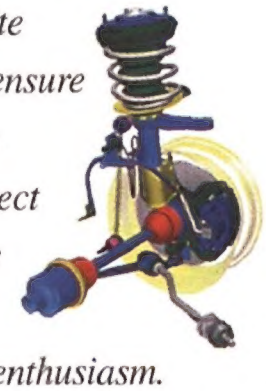


Under the short, sloping hood, an available aluminum multi-valve powerplant generates a stout 225 horsepower from a lean 3.2 liters of displacement. The Intrepid standard engine – a twin-cam aluminum wonder – produces 200 horsepower from just 2.7 liters. More power per liter than any other regular-fuel V-6 engine available today.

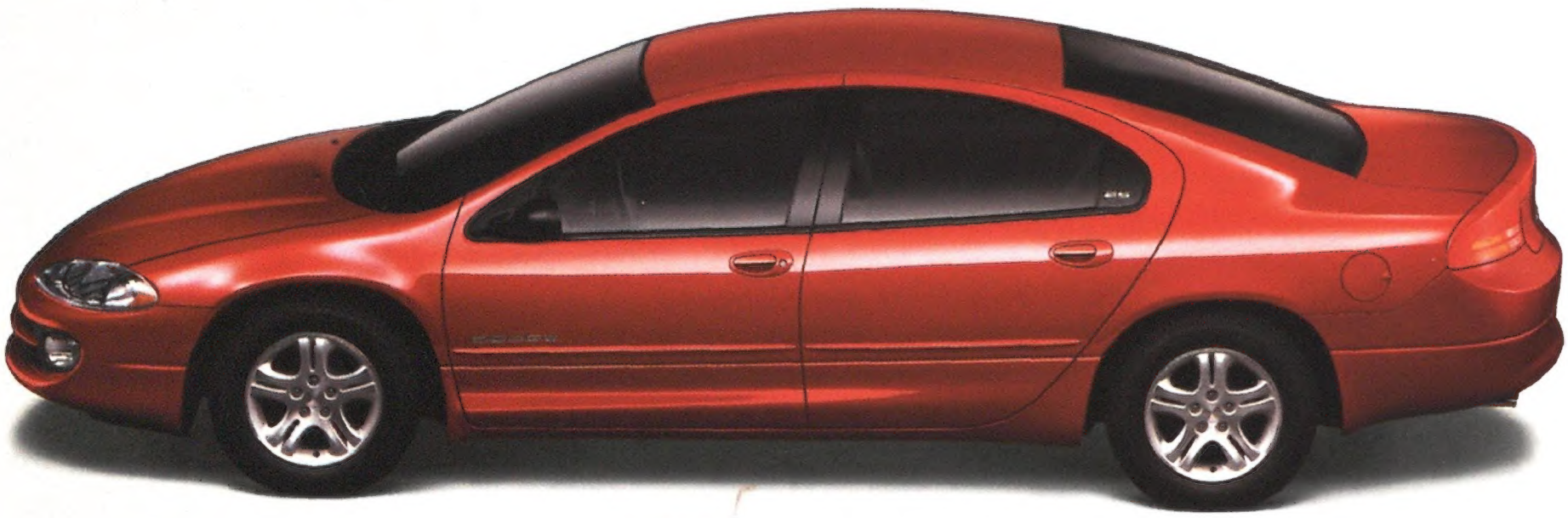


In the Intrepid ES cockpit, large, white analog instruments and a wrap-around console with AutoStick® shifter suggest that this is a place for serious driving. A fully independent suspension and fat tires on 16-inch aluminum wheels indicate that the suggestion is more than cosmetic. A remarkably rigid body/chassis unit – developed through extensive use of finite element analysis – helps ensure that the suspension will maintain correct geometry when the automobile is driven with enthusiasm. Dodge Intrepid. This changes everything. Again.





The stuff that makes it cook is even more advanced than its look.



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